Research Report 1394

Development of the Functional Requirements for Simulation in Combined Arms Training (SIMCAT)

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U. S. Army

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Subordinate leaders in armor units have been observed to have difficulty applying the C^3 (command, control, and communication) training they receive in the classroom to actual operations in the field. One means by which these leaders can practice C^3 skills before participating in field exercises is with the use of a computer supported battle simulation. This report contains the functional requirements and hardware configuration for SIMCAT, a computer supported battle simulation that will be used for conducting research on how

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to train command, control, and communication skills in a classroom environment. The functional requirements were derived from a variety of sources including representative tank platoon scenarios, ARTEPs, situational training exercises, and battle drills. Included are the process and representation requirements for terrain, movement, detection/identification, engagement, indirect fire, communication, a resources audit, time, and post-simulation feedback. SIMCAT will consist of six networked microcomputers (four trainee stations, and stations for the opposing force and the controller/trainer). The system will use videodiscs and computer generated graphics to provide audio visual cues, inherent in tactical situations, to all simulation participants. Voice synthesis and speech recognition technologies will permit trainees to control movement and firing using normal communication protocols.

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FOREWORD

Training of command, control, and communication (C^3) skills in the Army has historically been conducted in a field environment using actual equipment. The cost of such exercises is already very high and will continue to mount as new, more sophisticated, more costly weaponry and support systems are taken into the inventory. Basic skills are learned in a classroom environment (the "crawl" phase of training) and then integrated and practiced in these field exercises (the "run" phase of training). What has been missing is a useful method of practicing these C^3 skills during a training activity that bridges the crawl and run phases, a "walk" phase. Such a training method would allow soldiers to make the mistakes characteristic of soldiers new to the task in a low cost environment--low cost monetarily as well as in terms of equipment and terrain damage.

ARI has been searching for such a method and has developed a battle simulation that can be used to conduct research on this training problem. This battle simulation, called SIMCAT (Simulation in Combined Arms Training), will provide a vehicle for conducting research on C^3 training and performance in the context of the armor platoon. SIMCAT will be used to determine how subordinate leaders in armor units can learn to command and control their units while still in the classroom, thereby reducing the amount of time (and money) required for C^3 training in the field.

This report describes how the functional requirements for SIMCAT were developed, lays out those functional requirements in a new and innovative way so that hardware and software development flows easily from them, and describes the hardware solution resulting from the requirements.

EDGAR M. JOHNSON
Technical Director

DEVELOPMENT OF THE FUNCTIONAL REQUIREMENTS FOR SIMULATION IN COMBINED ARMS TRAINING (SIMCAT)

EXECUTIVE SUMMARY

Requirement:

The Army's Airland Battle doctrine has increased the command, control, and communication responsibilities of subordinate commanders and requires these commanders to make rapid decisions in combat. While classroom training provides insufficient practice in command and control, field training is both a costly and inefficient way to learn basic C^3 skills. One solution to this problem is to develop a low cost battle simulation that could serve as a link between the classroom and the field. Skills that are introduced in the classroom could be practiced on the battle simulation and later refined during practice in the field. It is the purpose of this project to explore this approach to training by developing a computer supported battle simulation, SIMCAT (Simulation for Combined Arms Training), that can be used as a research vehicle to determine how battle simulations can be used to train the subordinate commanders in a tank platoon (i.e., platoon leader, platoon sergeant, and tank commanders) to perform the C^3 skills required for effective coordination in combined arms operations.

Procedure:

The functional requirements for SIMCAT were derived from a variety of sources including representative scenarios, Army Training and Evaluation Programs (ARTEPs), situational training exercise (STXs), and battle drills. These requirements defined the processes and representations that SIMCAT must satisfy to achieve its intended training goals. Included among the categories of functional requirements were those pertaining to terrain, movement, detection/identification, engagement, and indirect fire. As the functional requirements were being prepared, information was obtained on the hardware, software, and peripherals that would be required to support the functional requirements.

Findings:

SIMCAT will consist of six networked microcomputers (four trainee stations, and stations for the opposing force and the controller/trainer) that will provide audio visual cues inherent in tactical situations to all simulation participants using videodiscs and computer generated graphics. Each trainee will be provided a display showing an overhead view of a map. Graphic representations of friendly and enemy weapon systems will be superimposed upon the map. Factors such as line of sight, distance, and obscurants will be taken into account in determining target identification. Voice synthesis and speech recognition

technologies will permit trainees to control tank movement and firing using normal communications protocols. Playback capabilities and simulation summaries will enable the controller/trainer to provide feedback to trainees.

Utilization of Findings:

When completed, SIMCAT will serve as a research vehicle to investigate how a computer supported battle simulation can be used as a link between the classroom and the field enabling students in officer and noncommissioned officer courses to practice command, control, and communications skills before participating in situational training exercises. It will also be usable to conduct research on how tank commanders, platoon sergeants, and platoon leaders can practice these skills in units when training areas are scarce or when resources such as ammunition and fuel must be preserved.

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DEVELOPMENT OF THE FUNCTIONAL REQUIREMENTS FOR SIMULATION IN COMBINED ARMS TRAINING (SIMCAT)

INTRODUCTION

Airland Battle, the Army's doctrine for the mid-1980's, advocates increased decentralization of command and control during combat. It is anticipated that the leaders of small units (e.g., squad leaders, platoon leaders, company commanders) will have greater latitude in exercising the initiative during combat operations than leaders of similar units have had in the past. This expectation is the result of a need to maintain greater dispersion among units as a defense against the increased lethality of opposing force (OPFOR) weapon systems, especially NBC weapons, and as a consequence of OPFOR interference in battlefield command and control. As a result of combat decentralization, subordinate leaders such as tank commanders, platoon leaders, and company commanders will have greater command and control responsibilities than their counterparts have had in the past. Adding to these responsibilities is the doctrinal requirement that subordinate leaders exercise agility in combat by making rapid decisions in order to counterbalance OPFOR superiority in manpower and weaponry.

Because of this change in the anticipated combat role of subordinate leaders, it has become increasingly important that these leaders be adequately trained in command, control, and communications (C^3). In the past many command, control, and communications skills were learned during combat itself. The present battlefield has become so lethal, however, that inadequately trained soldiers are unlikely to survive. Consequently, combat, control, and communications skills must be learned to standard before these soldiers enter combat. This will not only increase the likelihood of survival, it will also result in greater synchronization among the different elements of the unit during battle. Unfortunately, while the need for adequate C^3 training is rising, so are training costs. Resources such as fuel, ammunition, and equipment have become so expensive that training budgets have become strained. Adding to the difficulty of providing adequate C^3 training are shortages of training personnel and shortages of adequate training areas, particularly in Europe.

Due to problems such as these, the Army explored the use of tactical engagement simulation training systems. One of the earliest of these systems, SCOPES, used inexpensive hardware to enable two opposing forces to actively engage one another in a free-play environment. The extension of SCOPES from infantry platoons to armor units resulted in REALTRAIN. These systems eventually evolved into MILES (Multiple Integrated Laser Engagement System) in which lasers were used to assess battlefield casualties.

While tactical engagement simulation training systems eliminated the need for ammunition and provided a mechanism for assessing certain aspects of performance, the implementation of these training systems still required extensive resources such as fuel, weapon systems, and

training areas. Consequently, the Army began to explore the use of battle simulations for training. One of the earliest of these, TOX (Tactical Opposition Exercise), was a tactical game board which has since evolved from single player versions to combined arms versions. With the availability of computer technology, the Army expanded its exploration of battle simulations with the development of computer supported simulations such as BABAS (Battalion Automated Battle Simulation, formerly MACE), CATTS (Combined Arms Tactical Training Simulation), and ARTBASS (Army Training Battle Simulation). BABAS is a battle simulation designed for training battalion commanders and their staffs to exercise command and control skills during combat. CATTS and ARTBASS, similarly, are battle simulations designed for training command and control skills at the battalion level. Other battle simulations have also been developed for leadership training at higher echelons (e.g., ARTBASS, FIRST BATTLE). Despite the emphasis that has been placed on the development of battle simulations for training commanders and staffs at battalion level and higher, relatively little effort has been expended to create battle simulations for training leaders at lower echelons. Those that have been developed for use at company level or lower (e.g., TOX, Dunn Kempf), moreover, have not incorporated computer technology. Because of the lack of attention that has been given to the use of battle simulations for training command and control skills at lower echelons, there is a considerable gap between training in the classroom and training in the field that students find difficult to cross. A properly designed battle simulation may readily meet this need.

The potential value of battle simulations in training becomes especially apparent when examining the need for more efficient training of C^3 skills among the leaders assigned to tank platoons. The tank platoon, according to Division 86 doctrine, consists of four tanks. The platoon is under the command of a platoon leader who is also the commander of one of the four tanks. Assisting the platoon leader is a platoon sergeant who is the commander of one of the remaining three tanks. Each of the remaining two tanks is under the control of its own tank commander. The effective conduct of armor operations on the battlefield requires these four leaders and their crews to operate together as an integral unit under the command of the platoon leader.

At the present time, the C^3 skills required for effective coordination between the platoon leader, the platoon sergeant, and the two tank commanders in a tank platoon are taught in the classroom and trained and/or reinforced in the field. There is no current mechanism that will allow these leaders to practice coordination in command and control during institutional training, and it is a typical observation during field training that these leaders have difficulty applying the training they received in the classroom to actual operations in the field. While these difficulties can be overcome eventually through practice and repetition in the field, this method of training effective command, control, and communication is obviously expensive and inefficient. Given the high costs of field training and the shortage of both training sites and training personnel, it would be much more efficient to devise a procedure that would enable the leaders in a tank platoon to practice coordination before participating in field exercises. Once the basic

skills required for effective coordination are adequately learned at low cost, these skills can then be refined in the field.

One means by which the leaders in a tank platoon may be able to practice basic C^3 skills before participating in field exercises is through the use of a computer supported battle simulation. It is the goal of this project to develop a prototype battle simulation that may eventually be used for this purpose. This simulation, SIMCAT (Simulation for Combined Arms Training), is being developed for the U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) by the Human Resources Research Organization (HumRRO) with Perceptronics as its subcontractor. When completed, it will be used by ARI to conduct research on how to train C^3 skills in a classroom environment.

There are several advantages that a computer supported battle simulation would have over one that is not computer supported. One advantage is a reduction in number of support personnel required to operate the simulation. Most battle simulations are manpower intensive since they require a relatively large number of support personnel compared with the number of people who can be trained on them. A battle simulation can require several controllers as well as persons to control movement, indirect fire, and OPFOR activities. Since many of these functions can be performed by a computer, a reduction in support personnel can be achieved by using a battle simulation that is computer supported. Another advantage of a computer supported battle simulation is that it allows the simulation to be conducted in a closer approximation to real time. In addition, a computer supported battle simulation can provide for more effective feedback since the data required for feedback can be collected, stored, and reproduced using the computer.

The development of SIMCAT is taking place in a sequence of six tasks. This report describes the results of the activities that were performed during the first two tasks. During Task 1, the functional requirements for SIMCAT were derived from a variety of sources such as task inventories, Army Training and Evaluation Programs (ARTEPs), and situational training exercises (STXs). These requirements prescribed the specific processes and representations that would have to be incorporated into SIMCAT to enable it to fulfill its training research functions. During Task 2, these functional requirements were used to design the resulting battle simulation and to identify the specific hardware and software components that would have to be developed or purchased in order to develop a prototype version of SIMCAT.

The functional requirements contained in this paper were prepared by HumRRO and were provided to Perceptronics to serve as the basis for selecting the hardware for SIMCAT and for designing its software. Three factors were taken into account by HumRRO when preparing the functional requirements--(1) the purpose for which SIMCAT was being developed, (2) the ceiling placed on the total cost of the hardware, and (3) the cost of developing the required technology. As a result, functional requirements that were judged consistent with SIMCAT's purpose were rejected by HumRRO when either the hardware or technology development costs associated with them were known to be excessive. Once the

functional requirements were provided to Perceptronics, the same set of factors was again taken into account during the design of the system. Thus, functions were not implemented when the price of the hardware caused the system to exceed its cost ceiling or when the cost of developing the required technology was excessive. Consequently, not all of the functions specified in this report will actually be incorporated into SIMCAT, and conversely, SIMCAT will contain functions that are not specified in this report.

The purpose of this part of the report is to describe the functional requirements which served as the basis for the design and development of SIMCAT. Although SIMCAT was designed after these requirements were prepared, a description of SIMCAT is presented here to enable the reader to relate the functional requirements to the design of the system.

SIMCAT will contain six stations--four trainee stations, an OPFOR station, and a controller/trainer station. Each station will have a display showing an overhead view of a map. Instead of the standard military map, a nonmilitary version containing fewer navigational cues will be displayed. The display on two of the four trainee stations will be reversed so that correct procedures will be required for proper navigation.

Superimposed upon each display will be graphic representations or symbologies of friendly tanks controlled by the trainees and of enemy tanks and enemy infantry fighting vehicles controlled by an OPFOR player. Each trainee will be able to see symbologies representing his own tank and other weapon systems that are in his line of sight. Each trainee will be able to select from among three displays--a close-up view which will maximize terrain detail, a far view which will maximize the area of the display, and an intermediate view. The OPFOR display will show graphic representations of all OPFOR weapon systems and all friendly tanks that are within line of sight of an OPFOR weapon system. The display available for the controller/trainer will show all weapon systems regardless of line of sight.

Each trainee will be able to move his own tank, rotate its turret, communicate, generate smoke, and fire two of the tank's weapons--the main gun and the coaxial machinegun. The trainee will be able to move his tank and fire its weapons using voice commands as if an actual crew were present. The system will recognize certain commands and execute them accordingly. When a trainee issues a fire command, the system will execute the command and automatically determine whether or not the target is hit. If the target is destroyed, this information will be displayed to each trainee in line of sight of the destroyed target, to the OPFOR, and to the controller/trainer. The OPFOR will also be able to control the movement and firing of his weapon systems and will be able to implement automated control of movement and firing to compensate for the greater number of vehicles and weapon systems under his control. Under automatic control, the OPFOR will be able to select a destination and the system will automatically move the OPFOR weapon systems along an appropriate route. If the OPFOR decides to select his own movement route, he will be able to do so by designating points along the route he

wishes to travel. The OPFOR will be able to fire each weapon system manually or have them fire automatically using realistic opening times and hit probabilities.

Each trainee will bring his own CVC helmet to SIMCAT. He will communicate to his crew on an intercom although no crewmembers will actually be present. SIMCAT will react to selected commands from the trainee and, when appropriate, will respond. Communications among the trainees will be possible on a platoon net or with hand and arm signals. If a trainee communicates using hand and arm signals, a graphic representation of the signal will appear on the display of the other trainees who are in line of sight with the tank issuing the signal. The platoon leader and platoon sergeant will be able to communicate to the company commander and to the FIST FO on the company net. The platoon leader or the platoon sergeant will be able to use this net to call for indirect fire. The system will provide indirect fire and adjust it automatically. Communications will also be possible between the controller/trainer and each trainee and between the controller/trainer and the OPFOR. The controller/trainer will play the role of the company commander and the FIST FO in communicating with the trainees.

The controller/trainer will be able to monitor and play back all events and communications. A built-in feedback system will provide the controller/ trainer with data that can be used for providing feedback.

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TASK I: APPROACH TO THE DEVELOPMENT OF THE FUNCTIONAL REQUIREMENTS FOR SIMCAT

Approach

Before attempting to identify the functional requirements for SIMCAT, it was necessary to clarify the meaning of the term "functional requirements." In this document, functional requirements will be defined as the processes and representations that the SIMCAT system must satisfy to achieve its intended training goals. Processes are those functions that are necessary to permit tank platoon leaders, platoon sergeants, and tank commanders to perform tasks normally associated with the operation of a tank in a field environment. Representations are the visual and auditory stimuli to which tank platoon leadership personnel would normally be exposed in executing tactical activities in a field environment.

SIMCAT functional requirements could be derived from a variety of sources such as training objectives, representative tactical scenarios, task inventories, Army Training and Evaluation Programs (ARTEPs), situational training exercises (STXs), or battle drills. Adopting the functional requirements from any single source would have been risky because of the difficulty involved in determining the degree to which a set of scenarios is representative of combined arms operations or a task inventory is complete. For this reason, it was decided to draw upon all these sources collectively to synthesize the functional requirements. The sources included the following:

ARTEP 71-2, Army Training and Evaluation Program for Mechanized Infantry/Tank Task Force, 23 November 1981.

19K10-40 Task Documentation (Directorate of Training and Doctrine, U.S. Army Armor School), 25 January 1983.

Program of Instruction, Basic Noncommissioned Officer Course (BNCOC) 19K M1 Abrams (US Army Armor School), June 1983.

FM 17-15 (Test), The Division 86 Tank Platoon, April 1983.

TT 71-1/2, Division 86. Volume II: Company and Platoon, March 1982.

Once it had been determined from which data sources the functional requirements were to be derived, a starting point had to be identified. It was agreed that three representative scenarios would serve as this starting point. Two of these scenarios were then developed (hasty attack and movement-to-contact) and an outline of the defend battle position scenario was formulated. Each scenario reflected SIMCAT's

training goals, armor platoon task inventories, and doctrine, as well as ARTEPs and training techniques (e.g., battle drills, STXs).

With the initial focus on the scenarios, the functional requirements for SIMCAT began to emerge. However, the scenarios could not be viewed in isolation. Although they were based upon the aforementioned data sources (e.g., task inventories, ARTEPs, etc.), these sources had to be referenced repeatedly in conjunction with the scenarios before functional requirements could be determined. This was because the process and representation requirements could not be derived from the scenarios alone. An example of this occurred when a scenario required an M1 tank to engage an opposition force (OPFOR) tank. Although various conditional factors were specified (such as the locations of the vehicles), it could not be determined from the scenario alone what specific SIMCAT functional requirements were necessary. As a result, attention had to be focused on the other data sources (in this case, task inventories and FMs). The specific processes (e.g., movement, firing main gun) and representations (e.g., weapon signatures) that SIMCAT had to satisfy to accommodate the engagement described in the scenario were determined from these data sources. The result was an iterative, cyclic, and deductive procedure or approach to identifying SIMCAT's functional requirements.

Following initial review of the scenarios and other relevant data sources, ten categories of functional requirements were identified (see section that follows). Once this was done, it was then necessary to prepare each functional requirement in detail. During this process, several questions surfaced repeatedly which dictated the need to establish some guidelines in considering functional requirements. Specifically, the following guidelines were adopted:

- The 80% Solution - It was realized at the onset that SIMCAT could not accommodate all possible conditions experienced by armor platoons on the battlefield. Therefore, it was decided that the focus would be on conditions that were the rule rather than exceptions to the rule. Thus it was arbitrarily decided that a condition must have a high probability of occurring on the battlefield in order to be accommodated by the functional requirements.

- Cost Constraints - Robust research practice would dictate that the functional requirements for SIMCAT be determined primarily on the basis of its training goals. Reality, however, dictated limits to initial hardware configuration costs for SIMCAT. Given that the costs associated with a functional requirement could be estimated at the time it was identified, these costs could not be ignored. Therefore, cost constraints were considered and any functional requirement which would have necessitated a prohibitive expenditure was disregarded.

- Training Focus - Since SIMCAT is to serve initially as a research vehicle on training tank platoon leadership, it constantly had to be kept in mind that SIMCAT was not to

serve as either a tank gunnery or crew trainer. Gunnery and crew-related tasks and their associated functional requirements, therefore, were neither a primary concern nor, in many cases, even desirable.[1] For example, a TC has the option of sighting and firing the main gun. No functional requirements were identified for this activity for two reasons. First, sighting and firing the main gun was related to tank gunnery (a training subject in its own right). Second, since the gunner normally fires the main gun, the 80% solution was applied and the functional requirements attending TC firing were dismissed.

- System Design - The functional requirements were to be restricted originally to the processes and representations that SIMCAT must satisfy to achieve its training research goals. The hardware and/or software requirements were to be neither stated nor implied. However, some functional requirements dictated obvious hardware/software requirements. Where this occurred, these requirements were specified. As an example, one situation arose in which the only way that a particular set of functional requirements could be satisfied was through voice synthesis and speech recognition. Taking into consideration the fidelity requirements, the burden placed on the SIMCAT controller/trainer position, and the cost, voice technology was deemed the only feasible manner in which a particular set of functional requirements could be satisfied. Rather than expending the effort that would have been required to identify functions from which one would determine a need for voice synthesis/recognition, this requirement was stated directly.

- Fidelity - If SIMCAT could replicate a real battlefield environment (i.e., achieve 100 percent fidelity), one could be assured it would satisfy its research requirements and all current as well as future training requirements. However, even if such a system were technologically feasible, the cost would be prohibitive. Therefore, fidelity requirements were considered on a case-by-case basis as the functional requirements were developed. Although the level of fidelity required in a simulation has been the subject of much debate in research, satisfactory criteria or methodologies for determining simulation fidelity requirements have yet to be developed. However, since the issue of fidelity could not be avoided in defining the functional requirements for SIMCAT, subjective, but sound, fidelity criteria (based primarily on cost constraints, technological feasibility, and stated or implied training goals) were applied.

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[1]This is not to say gunnery- and crew-related activities were totally ignored. However, they were addressed only to the degree that they contributed to or detracted from the fidelity of a TC's C^3 activities.

Analysis of the Functional Requirements for SIMCAT

The functional requirements contained in this document were analyzed individually and collectively for several purposes. Specifically, these analyses determined:

- Availability of Existing and Alternative Technologies - Here it was determined which hardware technologies, software technologies, or combinations thereof currently exist that could satisfy each functional requirement. Alternative technologies (each resulting in varying degrees of fidelity) that could be used for satisfying each set of functional requirements were identified and documented.

- Cost - The costs associated with each technology alternative identified were determined and documented. These costs included not only hardware, but any associated software packages and/or the development of software.

- Allocation of Resources - Given technological alternatives and the costs associated with each, a resource allocation analysis was planned. This analysis would involve treating each functional requirement (individually or in sets) as the key variable. For each functional requirement, several levels of fidelity would be established (e.g., high, medium, low, and very low). For each fidelity level, a cost and benefit/ utility/desirability value would be assigned. The cost value would be based upon the technological alternatives and costs resulting from the previous analyses. The benefit/utility/ desirability value assigned to each fidelity level would reflect a subjective appraisal of the training value of that fidelity level in terms of such factors as transferability to a field environment and relevance to achieving training goals. Once each of these values for individual sets of functional requirements had been specified, resource allocation analyses would be performed. These analyses could be keyed to any variable contained in the database, e.g., benefit/utility/ desirability, fidelity, or costs.

- Alternative Configurations - The resource allocation analyses would have resulted in identification of alternative SIMCAT configurations. These alternatives would be described in terms of the variables considered in the resource allocation analyses, e.g., level of fidelity, costs, or benefits.

These analyses will be performed in the near future. The product of these analyses will be the identification of two alternative system configurations and associated costs, i.e., a high cost and a low cost configuration. It is anticipated that the high cost alternative will be capable of satisfying all the functional requirements specified in this

document. Conversely, it is realized that some of the functional requirements defined may not be satisfied by the low cost alternative.

Identification of Functional Requirements

SIMCAT must satisfy a multitude of vastly different functional requirements. To define these, some form of classification is required so that they can be organized and comprehensible. Such a classification evolved during the development of the functional requirements. Specifically, ten categories of functional requirements were classified as follows:

- Initialization - These functional requirements involve the system processes necessary to begin a SIMCAT simulation, e.g., identification of scenario conditions (such as TO&Es and missions for each of the opposing forces), speech enrollments (necessary if voice recognition is involved), and selection of terrain. Since initialization functional requirements are dependent upon the manner in which the remaining nine categories of functional requirements are going to be satisfied, this category of functional requirements has yet to be developed. Once it is resolved which functional requirements specified in this document are going to be pursued and the manner in which each is going to be satisfied, this category of functional requirements will be developed.

- Terrain - These functional requirements involve providing each SIMCAT position (i.e., controller/trainer, trainee, and OPFOR) with knowledge about the terrain in which he is operating, or, in the case of the controller/trainer, the terrain within which both the OPFOR and friendly forces are operating. These functional requirements are defined in terms of terrain characteristics, trafficability, and the perception requirements for each SIMCAT position.

- Movement - The process and representation requirements for movement are defined as they relate to the object that is moving, the rate of movement, the control of movement, and the perception of movement.

- Detection/Identification - This category of functional requirements concerns the relevant objects, events, and conditions of the simulation environment that may be detected and possibly identified by each participant in a SIMCAT simulation.

- Engagement - The purpose of the functional requirements for engagement is to resolve all encounters between the military weapon systems being simulated in a scenario. An encounter, in this context, is defined as the firing of one or more OPFOR or friendly forces weapon systems and the effect, if any, on the engaged targets.

- Indirect Fire - Dedicated indirect fire support will be provided to each of the opposing forces in all SIMCAT scenarios. To satisfy this requirement, SIMCAT must maintain a record of all indirect fire allocations, provide a means for requesting indirect fire, impact indirect fires, and represent the effects to appropriate SIMCAT positions. The representation and process requirements necessary to satisfy each of these are discussed in detail.

- Communication - The communication functional requirements are specified in terms of four communication networks (nets): platoon, company/team, tank intercom, and controller. The purpose of each net and the SIMCAT positions involved in each net are defined.

- Resources Audit - These functional requirements dictate that SIMCAT maintain an audit of all munitions and fuel expended by each weapon system and vehicle simulated in a scenario. Given a specified allocation of fuel or munitions, SIMCAT must audit the expenditures of these resources as they occur and prevent further expenditures once a resource has been exhausted.

- Time - These functional requirements dictate that SIMCAT be sensitive to and represent two different types of time: simulation time and real time. Each of these types of time will be discussed and information on the functional requirements regarding simulation time will follow.

- Post-Simulation - These functional requirements specify the SIMCAT processes necessary to support controller/trainer responsibilities associated with providing feedback to trainees. Post-simulation functional requirements are divided into three categories: visual playback, audio or communication playback, and hard copy outputs.

Descriptions of the Functional Requirements for SIMCAT

The following pages contain separate sections for nine of the ten categories of functional requirements identified previously.[1] Each section varies in format because the nature of each functional requirement varies. For example, some functional requirements emphasize process requirements while others emphasize representation requirements. In cases where the rationale for a functional requirement was obvious,

[1]Initialization, omitted here, is the one functional requirement that is dependent on how the other nine functional requirements are met.

the rationale was not documented; where a rationale was less obvious, an effort was made to document it. Where appropriate, tables and figures are used to further define functional requirements.

Terrain

The functional requirements for terrain are to provide the trainees and the OPFOR knowledge of the terrain in which they are operating, and to provide the controller/trainer knowledge of the terrain in which both the OPFOR and friendly forces (trainees) are operating. Terrain functional requirements are discussed below in terms of characteristics, trafficability, and perception.

Characteristics

Terrain characteristics are the natural and/or man-made objects found in the tactical scenarios inherent in SIMCAT. In the real world, an indefinite number or type of terrain characteristics are possible. SIMCAT terrain characteristics, however, are restricted to representations of the following:

- Man-Made Objects:
  - Intact bridge (i.e., overpass)
  - Blown primary road bridge over a stream
  - Paved secondary road
  - Major road (two lane, concrete)
  - Underpass (secondary road overpassing a major road)
  - Exposed mines across a major roadway
  - Hidden minefields
- Vegetation and Water:
  - Woods (traversable in a tank)
  - Open, traversable grasslands
  - Stream with depth of 12 feet or more
  - Small ponds
- Relief:
  - Hills with elevations ranging from 100 feet to 300 feet
  - Tank traversable ridge
  - Nontraversable (for tanks) stream bank

Trafficability

Trafficability is the effect of terrain on movement rates and traversability (e.g., tanks can traverse open, relatively flat grasslands, but cannot traverse a 30 foot high, 90° bank). Trafficability functional requirements do not dictate any representation requirements, but dictate several modeling requirements (i.e., friendly tanks should not be permitted to move at their maximum rate in wooded terrain). These modeling requirements are specified later in the section on movement functional requirements for SIMCAT.

Perception

Each SIMCAT position requires a somewhat different perception of terrain. This difference in perception only relates to the area or size of the piece (and, consequently the scale) of the terrain which is represented to each position. Specifically, these perception requirements are as follows:

- Trainees - Each trainee should have represented to him only the terrain which is within his line of sight given his location relative to terrain characteristics (e.g., vegetation and relief) and obscurants (e.g., smoke). Each trainee should be provided with a 360° perspective of the terrain given the aforementioned constraints. Because it is impossible for two tanks to occupy the same space simultaneously, this requirement dictates that each trainee be provided a somewhat different terrain representation. Also, since each trainee will have the ability to move in any direction at any time, each of these terrain representations will change, and it will be necessary for SIMCAT to represent each tank position on the terrain.

- OPFOR - There will be a single individual controlling all OPFOR vehicles and weapon systems.[1] These vehicles will seldom, if ever, be in close proximity to one another (correspondingly, in a real situation, seldom will each vehicle have all other vehicles in visual sight). Instead, they usually will be dispersed. Because the OPFOR player must be aware of the location of all of these vehicles at all times, and because they are likely to be dispersed, a large area of terrain (relative to what is to be represented to each trainee) must be represented to the OPFOR player. As in the case of the trainee position, only the terrain which is within the line of sight of the vehicles and weapon systems he is controlling should be represented to the OPFOR player. Once line of sight (360° perspective)

[1]There will be a maximum of ten OPFOR vehicles and/or weapon systems due to cost constraints.

for each OPFOR vehicle has been determined by SIMCAT, a terrain representation for each vehicle should then be presented to the OPFOR position.

- Controller/Trainer - The terrain represented to the controller/ trainer will encompass an area even larger than that presented to the OPFOR position. This is necessary because the controller/ trainer must be provided with a God's-eye view of the entire area occupied by both friendly forces and OPFOR. This functional requirement should not be interpreted to mean that the entire offensive zone of operation for the friendly force must be represented to the controller/ trainer at any point. This will seldom, if ever, be necessary. Instead, three possible controller/ trainer terrain representations are envisioned:

  - Initial Defensive Position - Once a defense has been established (by either an OPFOR or friendly force), the controller/trainer must be provided with a God's-eye view of the defensive zone. This zone should include all of the terrain within line of sight of all defensive positions collectively. At this point, it will not be necessary to represent the terrain within the line of sight of offensive forces.

  - Movement Zone - Once an offense force has crossed its LD (line of departure), the terrain represented to the controller/trainer need only show a God's-eye view of the offensive movement area. This terrain representation should be a composite of the terrain within the line of sight of all offensive vehicles collectively. At this point, it will not be necessary to represent the terrain within the line of sight of defensive vehicles.

  - Offense/Defense Merge - At the point where one or more offensive vehicles are within line of sight of one or more defensive vehicles, SIMCAT should automatically provide the controller/ trainer with a composite terrain representation of all terrain occupied by and within the line of sight of all offensive and defensive vehicles. This terrain representation need not include terrain to the rear of the defense nor to the rear of the last vehicle of the offense.

  NOTE: The three controller/trainer terrain representations should involve at least three different scale terrain representations. The approach should permit the controller/ trainer to switch views between offense and defense until detection occurs. At this point, the controller/trainer should have no control or choice of what is represented. Upon detection, the terrain representation should include all terrain within the line of sight of all vehicles (offense and defense) involved in the simulation. This perspective is necessary if the controller/trainer is to monitor all activities.

Movement

Determining what moves, the rate at which something moves, the control of movement, and the perception of movement are all critical to achieving the training objectives of SIMCAT. The movement functional requirements vary, depending on the SIMCAT position being addressed.

- Trainee - The platoon leader, platoon sergeant, and two tank commanders will each control the movement of his own tank. The movement functional requirements for this position are covered in the following subsections:

  - Trainee Tank Movement
  - Trainee Tank Engine Control
  - Trainee Turret/Main Gun Movement

- OPFOR - One person will control the movement of all OPFOR elements (i.e., tanks or other vehicles and their associated weapon systems). The movement functional requirements for this position are covered in the following subsections:

  - OPFOR Vehicle Movement
  - OPFOR T72 Tank Turret and BMP 73mm Gun/Sagger Movement

- Controller/Trainer - A single individual will be responsible for controlling the entire SIMCAT simulation. The control is limited to creating the initial conditions, monitoring the actions of both OPFOR and friendly forces for the duration of the simulation, and providing feedback to all participants both during and after the simulation. With respect to movement functional requirements for SIMCAT, it is the monitoring responsibilities of the controller that are of most concern. The movement functional requirements for this position are covered in the following subsection:

  - Controller/Trainer Movement Requirements

Each of these movement functional requirements, with the exception of trainee tank engine control, will be discussed individually in terms of direction, rate, control, and perception. For purposes of this discussion, these terms are defined as follows:

- Direction - The line or course (expressed in terms of degrees) on which a simulated vehicle and its turret (in the case of a trainee only) are permitted to move.

- Rate - The speed at which a simulated vehicle or turret is moving.

- Control - The manner in which both the direction and rate of movement of the simulated vehicles or turrets are controlled. Control requirements will vary depending on the SIMCAT position being addressed.

- Perception - The visual image of movement which must be portrayed to each SIMCAT position. The visual image movement requirements will vary depending on the particular position.

Trainee Tank Movement

A trainee will be responsible for controlling the movement of his tank in all situations, including combat. In this context, movement includes both the direction in which a tank moves and its rate of speed. It is imperative that SIMCAT permit the trainee to control the movement of his tank. Specifically, this requires SIMCAT to satisfy the following functional requirements:

Direction. Each trainee must be capable of moving his tank in any direction (i.e., 360°) at any point on terrain representation, and at any time during simulation.

Regarding the area of operation, SIMCAT must restrict movement to the platoon zone of operation. SIMCAT should automatically prevent a trainee from moving outside of this zone by automatically generating a message from the company team leader advising the trainee of his error.

Rate. Maximum rate of speed for M1 Abrams tanks will differ depending on the following terrain characteristics or driving conditions:

Primary and Secondary Roads: 40 MPH

Open, Traversable Grasslands: 20 MPH

Wooded Areas: 10 MPH

Any Grade: 20 MPH

Stream Ford: 4 MPH

Moving in Reverse: 10 MPH

NOTE: These are maximum speeds for the conditions specified. Trainees have the option of moving at slower rates (see below).

Control. Each trainee must have control of both the direction and rate at which his tank is moving. To achieve the fidelity necessary to satisfy training requirements, this control should involve tank commander-to-driver voice commands as follows:

- Controlling Direction - Direction of tank movement must be controlled verbally by each trainee using formal driving commands. These commands will be restricted to the following:

- "Driver Move Out" (Tank must respond by moving forward, i.e., the direction in which the tank is pointed at the time the command is given).

- "Driver Stop"

- "Driver Turn Left"

- "Driver Turn Right"

- "Driver Guide Left"

- "Driver Guide Right"

- "Driver Steady On"

- "Driver Rear" (Tank must respond by moving in reverse, i.e., the opposite direction in which the tank is pointed at the time the command is given).

- "Driver SAGGER, SAGGER" (Tank will continue in the direction of the last command, but must begin to zig-zag. The zig-zag movement pattern must continue for fifteen seconds or until another driving command is issued, whichever occurs first).

NOTE: Given a movement command, the tank must continue to follow that command until another command is issued or until a nontraversable terrain feature is encountered. In other words, SIMCAT will assume a nonintelligent (i.e., non-decision-making) driver. Therefore, a tank will not stop automatically at the crest of a hill; it will stop only when the TC issues a stop command to the driver.

- Controlling Rate - Following a direction command, rate of movement must be at the maximum rate of movement given terrain characteristics (see previous section on controlling rate). However, the TC must be able to decrease and subsequently increase his tank movement rate at any time. Therefore, to control the rate of movement, the following TC-to-driver voice commands and subsequent movement rates are required:

  - "Driver Slower" - The rate of movement is immediately decreased by 50%. This command can be issued until the tank reaches 2 MPH, at which time the system will ignore any additional "Driver Slower" commands. For example, if a tank is moving at 40 MPH and the TC issues a "Driver Slower" command, movement rate is decreased to 20 MPH. If at this point, the TC issues another "Driver Slower" command, the movement rate is decreased to 10 MPH. Should another "Driver Slower" command be issued, the movement rate immediately decreases to 5 MPH. Should the TC issue another

"Driver Slower" command, SIMCAT would decrease the speed to 2-1/2 MPH. Any additional "Driver Slower" commands would be ignored by SIMCAT because the resulting speed would be less than the 2 MPH minimum speed allowed.

- "Driver Faster" - Tank movement rate doubles until maximum rate of movement is obtained. Because the rate of movement will always be the maximum rate of movement given terrain characteristics, this command will be effective only when it follows one or more "Driver Slower" commands. If a tank is moving at the maximum rate and the TC commands "Driver Faster," the SIMCAT response should be "I can't go any faster!"

NOTE: If at any point a tank is moving at less than maximum rate and a "SAGGER, SAGGER" message is issued, tank movement rate should automatically resume maximum movement rate and begin a zig-zag pattern.

Perception. Each trainee must always be aware of the following regarding movement of his tank.

- Tank Orientation - The front of a trainee's vehicle must always be indicated in some manner. This is necessary because the trainee must be aware of the orientation of his tank before he can determine the appropriate direction command to be given.

- Direction of Movement - Any time a trainee's tank is moving, the trainee must be made aware of the direction of that movement.

- Rate of Movement - Each trainee must be capable of discerning the movement rate of his tank. To accomplish this, the movement rate of the tank symbologies should be to scale depending on the terrain representation. Having done this, the trainee hopefully should be able to distinguish among varying rates of movement of his tank.

Trainee Tank Engine Control

Trainees will be controlling simulations of M1 Abrams tanks. Since these tanks have a rapid fuel consumption rate, a trainee may choose to turn the engine off when his tank is stationary (e.g., when defending a battle position). When the engine is off, power for the tank's systems (e.g., thermal imagery sight (TIS), tank turret movement) is provided by batteries. Therefore, SIMCAT must provide each trainee the capability to control the running of his tank's engine. This dictates the following tank engine control functional requirements.

Control. Each trainee position must be provided the capability to turn the tank engine to "off" and "on." Although this is normally

accomplished via commands from the TC to the driver, this level of fidelity is not required. A simple "Engine On" and "Engine Off" button would suffice. It should be noted that when an engine is turned to "off" the tank should not respond to TC-to-driver movement commands.

Perception. SIMCAT must provide a constant cue to the trainee signifying whether or not the engine on his tank is running. However, as was the case with control, fidelity is not of great concern. Therefore, SIMCAT need not necessarily provide a constant "engine running" auditory cue (e.g., the sound of an engine running when the engine is running) nor constant "silence" when the engine is not running. An acceptable alternative might be to have the "Engine On" and "Engine Off" buttons light up when one or the other is in effect.

Trainee Turret/Main Gun Movement

The position of the turret (i.e., the orientation of the main gun) is critical to combat effectiveness of a tank. Since main gun orientation is the responsibility of the tank commander, it is imperative that SIMCAT attend to the following functions associated with turret/main gun movement:

Direction. At any point, the trainee must be capable of positioning the turret/ main gun in any direction (i.e., 360°). He must be able to do this whether the tank is stationary or moving.

Rate. Turret/main gun movement rate is not of great concern. However, it should neither require a great deal of time nor occur at such a rapid rate that it is difficult to control.

Control. The mechanism or procedure for positioning the turret/ main gun need not be high fidelity. SIMCAT artifacts (e.g., joystick, function keys) are acceptable.

Perception. Each trainee must always be aware of the position of the turret on his tank. Again, fidelity is not of concern; some form of symbology is acceptable.

OPFOR Vehicle Movement

Movement of all of the vehicles and weapon systems under his control is essential to the OPFOR position. SIMCAT, therefore, must provide the OPFOR position the capability to move his vehicles both individually and together as a group. This would dictate the following OPFOR vehicle movement functional requirements:

Direction. At any point on terrain representation, and at any time during simulation, the OPFOR position must be capable of moving any of the vehicle and/or weapon systems he controls in any direction (i.e., 360°). He must be permitted to move each of his vehicles individually as well as in unison. The latter requirement is necessary in situations where several of his vehicles are in contact and the time required to

move each vehicle individually would be prohibitive (e.g., would result in exposure of his vehicles to enemy fire for an unrealistic period of time).

Rate. Rates of movement would be identical to those specified for friendly force tanks. Under all conditions, OPFOR vehicles will move at maximum rates given the constraints imposed by terrain features, obscurants, and illumination.

Control. Given that the OPFOR position must have the ability to control up to ten vehicles, fidelity in terms of TC-to-driver commands is not possible. Nor would it be feasible to provide joysticks with which the OPFOR player would control the movement of the vehicles individually (because of the time that would be necessary to move each vehicle individually). Therefore, the OPFOR position must have the capability to quickly identify the vehicle he wishes to move and the location to which he wishes to move it. SIMCAT would then initiate the movement, control its movement rate, and automatically stop the vehicle when it reached the point designated by the OPFOR position. The OPFOR position should be permitted to designate movement of each vehicle immediately following each movement command. This would necessitate that SIMCAT control the movement of several OPFOR vehicles simultaneously. Aggregate control of three, possibly more, OPFOR vehicles (BMPs and/or T72s) should be considered.

Perception. The OPFOR position must be cognizant of the location and movement of each of the vehicles under his control at all times. Line of sight or intervisibility among OPFOR vehicles is not of concern.

OPFOR T72 Tank Turret and BMP 73mm Gun/Sagger Movement

As was the case for trainees, the positioning or orientation of OPFOR tank main guns and BMP 73mm gun/SAGGERs are critical factors which must be considered in SIMCAT. These considerations should address direction, rate, control, and perception.

Direction. At any point, the turret on each OPFOR tank and the gun or SAGGER on each BMP must be capable of being oriented in any direction (i.e., 360°). The orientation of each turret and gun or SAGGER must be capable of being changed at any time whether the weapon system platforms (i.e., a tank for an OPFOR main gun and BMP for SAGGERs or 73mm gun) are moving or not.

Rate. The rate of orienting or moving an OPFOR tank turret and BMP 73mm gun or SAGGER is irrelevant since SIMCAT will orient them automatically.

Control. Manual control of OPFOR tank turrets and BMP 73mm gun or SAGGER orientations by the OPFOR position is neither necessary nor desirable. SIMCAT should automatically orient these weapon systems in tactically appropriate positions. In other words, SIMCAT should assume that OPFOR tank main guns and BMP 73mm guns or SAGGERs are properly oriented at all times.

Perception. If it is assumed that all OPFOR tank main guns and BMP weapon systems are properly oriented at all times, there is no need to cue the OPFOR player of these orientations either symbolically or by any other means.

Controller/Trainer Movement Requirements

To assess tactical situations and provide proper feedback to trainees, the controller/trainer must always be aware of what is moving, at what speed things are moving, and the orientation of friendly tank main guns. This necessitates that SIMCAT satisfy the following functional requirements:

Direction. The controller/trainer must be aware at all times of the direction of movement of all vehicles (friendly and OPFOR) in the simulation. In addition, the controller/trainer must always be aware of the direction/ orientation of the main guns on friendly force tanks.

Rate. The controller/trainer must be aware of the movement rate of each vehicle in the simulation (see section on perception, below).

Control. The controller/trainer need not have any control of the direction of movement or movement rate of either OPFOR or friendly forces, nor of the orientation of the main guns on friendly force tanks.

Perception

The controller/trainer must be aware of the following at all times:

- Vehicle Orientation - The front of all friendly and OPFOR vehicles must be obvious to the controller/trainer.
- Friendly Force Turret/Main Gun Orientation - The position of the main guns on all friendly force tanks must be obvious to the controller/trainer. This need not be accomplished for OPFOR tank main guns or other OPFOR weapon systems which are always assumed to be properly oriented.
- Movement - The direction in which any simulation vehicle (i.e., friendly tank or OPFOR vehicle) is moving must be portrayed to the controller/trainer.
- Movement Rate - The movement rate of any simulation vehicle must be discernable to the controller/ trainer. This does not necessarily dictate that all movement must be depicted to scale nor depicted in continuous motion. For example, a symbol could move in 1/4-inch increments as opposed to moving continuously at an extremely slow, possibly nondetectable, rate. However, the controller/trainer should be able to distinguish rapid from slow movement rates.

Detection/Identification

These functional requirements concern the relevant objects, events, and conditions of the simulation environment which may be detected and subsequently identified by each participant in a SIMCAT simulation. These functional requirements not only concern what can be seen and heard, but also address the manner in the stimuli are to be represented to the SIMCAT positions. In general, these functional requirements must consider the detection of the following:

- tanks (MIs, T72s)
- BMPs
- instantaneous events (weapons signatures, other noises and flashes)
- transient conditions (smoke, dust, engine noise)

These functional requirements must also address how to determine when detection has been lost by each SIMCAT position.

It should be noted that detection, in this context, is not restricted to detecting only opponent forces (i.e., OPFOR detecting friendly forces and friendly forces detecting OPFOR forces). In this case, detection means that friendly forces must have the ability to detect other tanks in their platoon that are within their field of vision; and in the case of the OPFOR, that all OPFOR vehicles must be represented to the OPFOR position at all times regardless of line of sight restrictions between OPFOR vehicles. However, the OPFOR ability to detect friendly forces must be restricted by line of sight and other considerations.

The detection/identification functional requirements for SIMCAT are best defined in terms of visual detection, visual identification, auditory detection/location, and representation requirements.

Visual Detection

To determine whether an OPFOR or friendly force vehicle detects something visually, two questions must be answered--"Can it be detected?" and "Do they see it?" To answer the first question, SIMCAT must determine whether or not line of sight exists. Terrain characteristics[1] (i.e., man-made objects, vegetation and water, and relief) located between the friendly or OPFOR simulation vehicle and the potentially detectable object, event, or condition must be considered in

[1]Terrain characteristics are addressed in detail in SIMCAT Terrain Functional Requirements.

determining line of sight. If line of sight does exist, the range (i.e., distance between possible detector and detectable object) must be considered to answer the second question ("Do they see it?"). Many variables must be considered to determine the effect of range on detection. These would include the size and disposition (i.e., stationary or moving) of the detectable object and its persistence (e.g., solid object, flash, smoke), all of which are mediated by the possible use of sighting devices. With respect to sighting devices, SIMCAT must always assume that friendly forces have available to them both binoculars and thermal imagery sights (TIS). It should also be assumed that OPFOR will have binoculars (but not TIS). As a result, the magnification capability of both binoculars and TIS must be considered at ranges which normally would eliminate any possibility of detection by the naked eye. Where smoke exists, SIMCAT must always assume that friendly forces will use their TIS to permit them to see through it.

Visual Identification

Once the system has considered line of sight and range and has determined that an object can be detected, an additional question must then be asked--"What does he see?" Detection does not necessarily mean absolute, 100 percent identification. When a distant object is detectable from a SIMCAT vehicle, the degree to which it can be identified must then be determined.

Three variables can affect the degree to which a detected object can be identified and should be considered by SIMCAT. The first of these is range. For example, the turret of a tank is far easier to identify at a range of 300 meters (with or without visual aids such as binoculars) than it would be at 1100 meters. The second variable is the distortion associated with the use of a Thermal Imagery Sight and its impact on the probability of identifying a detected object. The third variable is the presence of obscurants such as dissipating smoke. A detected object seen through a dissipating smoke screen is likely to be more difficult to identify.

Auditory Detection/Location

Auditory detection requires that the sound source be within range of a possible detector. Range or distance from the possible detector is not the only variable to be considered, however. The noise level of the environment within which the possible detector exists (e.g., a tank with engine running) must be considered as well as the source sound level. The computation used to determine the requirement to represent an auditory cue should also consider most of the variables previously addressed regarding line of sight (e.g., terrain characteristics) all of which could affect noise detection.

Representation Requirements

Given that SIMCAT has determined that the occupants of one or more SIMCAT vehicles (OPFOR and/or friendly) have visually detected something (e.g., vehicle or weapon signature) or are to be provided with an auditory cue, SIMCAT must represent this cue in some way to the appropriate vehicle(s). Specifically, these cue representation requirements are as follows:

- Auditory - Both the type of noise (e.g., running engine, explosion) and approximate location of the noise source must be represented. The location should be approximate and need not be entirely accurate because it is extremely difficult to determine the exact direction and range of a noise source. Equally important to representing the presence of an auditory cue is cueing the SIMCAT participant when the noise has ceased.

- Location of Detected Object, Event or Condition - This representation requirement is twofold. First, SIMCAT must designate to the detector the location of the object, event or condition. Second, the system must represent the object, event, or condition itself in a manner which permits the detector to distinguish it to some degree.

- Identification of Object, Event or Condition - SIMCAT must do this to some variable level of accuracy. For example, SIMCAT will be required, no doubt, to represent a T72 tank in several different ways depending upon conditions (e.g., range, presence of obscurants, use of TIS). A fully exposed T72 seen from the side at a range of 300 meters through binoculars would be represented in an entirely different manner than a T72 detected at 2000 meters in defilade through a TIS. In the former condition, the T72 would probably be identifiable as a T72 tank. In the latter condition, it would probably be identifiable as "some type of vehicle."

- Loss of Detection - SIMCAT must also provide some form of notification that detection of an object has been lost or degraded. Examples of degraded detection would be a tank moving at a rapid rate away from the detector, or a dissipating smokescreen or weapon's signature.

All of the cue representation requirements listed above are equally applicable to all SIMCAT positions (i.e., trainees, OPFOR, and controller/trainer). However, the OPFOR and controller/trainer SIMCAT positions have additional cue representation requirements as a result of the God's eye perspective to be provided each of these positions.

Specifically, SIMCAT must not only provide the controller/trainer and OPFOR positions with detection/identification cues, it must also designate which SIMCAT vehicle(s) is doing the detection. For example,

the single individual occupying the OPFOR position will constantly be provided with representations of all OPFOR vehicles and weapon systems involved in the scenario regardless of dispersion and intervisibility. Should SIMCAT determine that one of these vehicles (there could be as many as ten) detects an object, event, or condition and the other vehicles do not, a problem arises. SIMCAT must represent the cue in some manner to the OPFOR position. However, before the OPFOR position can take any action (e.g., engage the object, take evasive action), he must be made aware of the specific vehicles that have detected the object. Therefore, this detection/detector relationship and representation requirement becomes critical.

A somewhat similar detection/detector relationship problem arises in the controller/trainer position. If the controller/trainer is to provide complete and accurate feedback, he must know who sees and/or hears whatever is detected, as well as when the detection occurs. As a result, the detection/ detector relationship representation must be provided to the controller/ trainer for both the OPFOR and friendly forces.

Should detection from an OPFOR vehicle and/or friendly tank be distorted as a result of TIS usage, range, and/or the presence of smoke, the controller/trainer representations must reflect these conditions.

Engagement

The purpose of the engagement functional requirements for SIMCAT is to resolve all encounters between the military vehicles being simulated in a scenario. An encounter, in this context, is defined as the firing of one or more OPFOR or friendly force weapon systems. Engagement functional requirements involve five basic requirements. First, SIMCAT should model the operational characteristics associated with the use of various weapon systems, including variables such as reload times. Second, SIMCAT should model the potential effects resulting from the use of weapon systems including vehicle/ equipment/weapon system damage and destruction, personnel kills, and suppression. Third, the effects, if any, of a successful engagement by a weapon system (i.e., a hit) must be represented to the different SIMCAT positions (i.e., controller/trainer, OPFOR, and trainees) with varying degrees of specificity. For example, if one tank engages another and obtains a direct hit, the tank that was hit certainly would know that his turret is no longer functioning, while the tank firing the round would not necessarily be aware of this fact. Fourth, the detectable events and conditions created as a result of a weapon system firing (i.e., weapon signature, impact of munitions) must be represented to the appropriate SIMCAT positions. Fifth, SIMCAT must maintain an audit of the amount of munitions expended by each weapon system.

SIMCAT's engagement functional requirements can be specified best by addressing each of the following:

- Weapon Systems Involved
- Control of M1 Abrams Weapon Systems
- Control of OPFOR Weapon Systems
- Weapon Effects Modeling
- Representation Requirements

Weapon Systems Involved

One of the most critical factors or variables that must be considered in the development of engagement modeling and representation processes is the weapon system involved. In the initial version of SIMCAT, there will only be a few weapon systems although the number can easily be increased at a future date. The weapon systems and their associated basic loads are specified in Table 1.

Table 1

SIMCAT Weapon Systems and Their Associated Basic Loads

WEAPON SYSTEM	BASIC LOAD
Friendly Forces (i.e., M1 Tank):	
Coax	10,000 rounds (every 5th round a tracer)
Main G	33 rounds (APFSDS (735 series or up)
	22 rounds HEAT
Mines	4 A.T. Mines
OPFOR (i.e., T72 and BMP):	
T72 Main Gun	40 rounds HAVAPFSDS
SAGGER (mounted on BMP)	4 rounds
73mm Gun (on BMP)	40 rounds (assume all are HEAT)
Mines	Type and number to be determined

The basic loads specified in Table 1 for each weapon system represent the maximum number and type of rounds that should be allocated for that weapon system. While the controller/trainer should not be able to increase these numbers in any scenario, he should be permitted to decrease them if he desires to do so.

Control of M1 Abrams Weapon Systems

Each SIMCAT trainee position will have total control of the tank weapon systems at that position. An M1 tank has four weapon systems aboard: the tank main gun, a coax machinegun, a .50 caliber machinegun, and the loader's 7.62mm machinegun. Only the tank main gun and the coax machinegun will be simulated in SIMCAT. On an M1 tank, the main gun and coax can be fired by either the gunner or the TC. In SIMCAT, however, only the gunner[1] will be permitted to fire these weapons.

Given that only the tank commander will be present during a simulation, SIMCAT has certain M1 weapon system control functional requirements it must satisfy. These requirements can be defined most easily by addressing the tank main gun and coax collectively.

- Control of Tank Main Gun and Coax - Both the tank main gun and coax on an M1 tank can be controlled by either the gunner or TC. As stated previously, in SIMCAT, the TC will not be permitted to actually fire either of these weapons systems. Instead, the TC will issue fire commands to the gunner and loader in the same manner that he would in a real tank. In SIMCAT, these commands could be handled in a number of ways (e.g., voice synthesis/ recognition, function keys, screen menus with keyboard inputs, textual input/output). It is highly desirable that voice synthesis/ recognition technologies be employed. This is the only alternative that will provide the fidelity necessary to achieve training objectives. For the remaining discussion of this function requirement, it is irrelevant which technology will eventually be used. If voice technology is used, it can be assumed that sending messages from the gunner to the TC will involve voice synthesis. If voice technology is not used, it can be assumed that a textual output on a CRT will be used.

  Once a trainee has identified a target he wishes to engage with either the coax or the main gun, SIMCAT must first allow the trainee to traverse the turret so that the main gun and coax are pointed in the general direction of the target (this functional requirement is addressed in detail in the discussion of SIMCAT's movement functional requirements). Once this has been accomplished, SIMCAT must

[1] In actuality, the gunner position will be simulated.

accommodate (through voice recognition/ synthesis, function keys/textual output, etc.) a series of trainee gunner and loader verbalizations. The sequence of commands and verbalizations and the functional requirements related to them are as follows:

- TC Provides Alert to Gunner - The TC will call out "Gunner!" over the tank intercom. This alert normally is provided at the same time the TC is traversing the turret in the general direction of the target. The purpose of the command is to alert the gunner that the TC wants him to engage a target.

- TC Identifies Weapon System to Engage - The gunner, having been alerted that he should prepare to engage a target, now must be told which weapon system (coax or main gun) he should use to engage the target. If the TC wants the gunner to engage the target with the coax, the TC's next command over the tank intercom will be simply, "Coax!" If the TC wants the gunner to engage the target with the tank main gun, the TC's next command over the tank intercom will be either "HEAT!" or "SABOT!", specifying which of the two types of tank main gun rounds should be used. This command will actually be directed at the loader who will load the round specified.

- TC Describes Target - The TC will then describe over the intercom the target to be engaged (e.g., "Tank," "BMP"). SIMCAT need not recognize the target description given by the TC because SIMCAT will be controlling the gunner actions and will be aware of what the TC has detected. Therefore, SIMCAT can ignore this portion of the firing command.

- Loader Announces Message - Next, the loader will announce "Up!" when the round has been loaded. SIMCAT must provide this message to the trainee (over the tank intercom, if voice synthesis is used).

- Gunner Announces Message - SIMCAT must then provide the message "Identified" from the gunner to the TC (over the voice intercom if voice synthesis is used).

- TC Gives Fire Command - Once the loader has said "Up" and the gunner has said "Identified," the TC will give the command "Fire!". At this point, SIMCAT should cause the tank main gun or coax (depending on the weapon system specified by the TC earlier) to fire.

- Gunner Gives Fire Response to TC - If the tank main gun is to be fired, SIMCAT must output the message "On the Way!" from the gunner to the TC over the tank intercom.

- Subsequent Firing Activity - At this point during main gun firing, several activities are possible, depending upon certain conditions (e.g., whether or not the round hits its target, whether or not the gunner can see the round impacting down range). In SIMCAT, the conditions subsequent to main gun firing will be held constant. Specifically, it will always be assumed that the gunner can see the target and, when a HEAT round has missed, that the gunner will always be able to determine if the round was short, long, or to the left or right of the target being engaged, but not when a SABOT round has missed since it cannot be detected. Given that these conditions will be held constant, there no longer will be any requirement for the TC to communicate with the gunner or loader. However, the gunner will have to provide feedback to the TC. This feedback will vary depending on whether or not the target was hit, as in the following situations:

  - If the target was hit, the gunner (i.e., SIMCAT) will tell the TC "Target" over the tank intercom.

  - If the target was missed, the gunner (i.e., SIMCAT) will tell the TC "Re-engaging." Given that the gunner will always be presumed to have seen the target and the relationship of the target to the area where his missed round impacted, the gunner will fire automatically at the target once again. This will continue until the target is hit.

NOTE: If a target disappears (e.g., moves out of sight), SIMCAT should automatically cease all gunner activities. In addition, the TC should be able to issue a "Cease Fire" command to the gunner to signify that he wishes the gunner to stop firing.

Control of OPFOR Weapon Systems

The individual occupying the SIMCAT OPFOR position will be provided at all times with representations of the location and movement of all OPFOR vehicles as specified in the sections on SIMCAT movement, terrain, and detection/ identification functional requirements. It is this condition that dictates most of the functional requirements associated with the control of OPFOR weapon systems (which differ considerably from the functional requirements for friendly force, i.e., M1 Abrams weapon system control). Specifically, SIMCAT must provide the OPFOR position the capability of either manually controlling the weapon systems of OPFOR vehicles or allowing SIMCAT to control OPFOR weapon system firings automatically. Manual weapon system control would necessitate the following functional requirements.

- Identification of Weapon Platform To Use - Given that the OPFOR position will have represented to him, at all times, the location of all his weapon system platforms (i.e., BMPs and T72s) as well as anything detected (i.e., potential targets) by each platform, he must have the capability to identify which weapon platform he wishes to fire.

- Identification of Weapon System - As stated previously, two weapon platforms will be involved in the OPFOR forces--T72 tanks and BMPs. Only one T72 tank weapon system will be simulated--its main gun. Therefore, when the OPFOR position selects a T72 as the weapon platform he wishes to fire, it will always be its main gun that fires. However, should the OPFOR position select a BMP as the weapon platform to engage a target, there are two weapon systems that could fire--a 73mm gun and a SAGGER. Therefore, whenever the OPFOR position identifies a BMP as the weapon platform to engage, SIMCAT must also permit him to select which weapon system(s) on board the BMP he wishes to fire--the 73mm gun, the SAGGER, or both.

- Target Identification - At any time, a single OPFOR vehicle (i.e., T72 or BMP) may have simultaneous, multiple target opportunities. In addition, since all OPFOR vehicles will be represented to the OPFOR vehicles along with anything that may be detected from each OPFOR vehicle, one must anticipate the possibility that an OPFOR position may misinterpret SIMCAT cues and select a weapon platform to engage a target that could not be detected from that weapon platform. This could happen, for example, when two OPFOR vehicles are in close proximity. A target is detected from one OPFOR vehicle which the SIMCAT appropriately represents to the OPFOR position. The OPFOR position could mistakenly interpret this cue and specify that he wishes the OPFOR vehicle which did not detect the target to engage it. SIMCAT must permit the OPFOR position to identify the target that he wishes to engage. If, as a result of misinterpreting SIMCAT cues, the OPFOR position associates the target with a weapon system that has not detected the target identified by the OPFOR position, SIMCAT must provide the OPFOR with appropriate feedback.

Once a battle begins, the OPFOR position may have difficulty tracking each of his individual vehicles and associated weapon systems. Therefore, SIMCAT must have the capability to automatically fire OPFOR weapon systems should the OPFOR position desire SIMCAT to do so. This simply means that SIMCAT should perform the fire control processes without requiring the OPFOR position cueing it to do so (i.e., when an OPFOR vehicle detected a target, it would automatically engage the target with the most appropriate weapon system after an appropriate time delay). The OPFOR position should be capable of designating "automatic fire control" for a single or for multiple OPFOR vehicles. He should also be permitted to switch from automatic to manual fire control whenever he desires to do so.

Weapon Effects Modeling

The functional requirements for weapon effects can be viewed as consisting of two major processes--determination of single weapon effects and determination of aggregate weapon effects. Each will be discussed individually.

When one or more weapon systems engage a single target, SIMCAT must determine the effects of the weapon system(s) firing on the target engaged. Two subprocesses are involved--hit probabilities and, if the target is hit, consequential damage to the target. At a minimum, hit probabilities must consider the following variables:

- Distance to target
- Type of target (e.g., size relative to what it is, range, etc.)
- Target disposition (e.g., stationary or moving, fully or partially exposed, front/rear/side view) Presence (and degree of) or absence of obscurants (e.g., smoke dust)
- Firer disposition (e.g., stationary or moving, using TIS)

After having determined whether or not the target was hit, SIMCAT must next determine what damage, if any, the target suffered as a result. It should not be assumed that a target is destroyed anytime it is hit. For example, an M1 tank that receives several direct hits from a 73mm gun on a BMP would not be destroyed in most cases. However, the possibility does exist that the mobility of the tank may be affected if a road wheel is damaged or destroyed or if a track is thrown. Therefore, SIMCAT must consider the following variables to determine the extent of damage to the target that has been hit:

- Ballistics of impacting munitions (e.g., HEAT main gun round, point detonating 155mm, 73mm HEAT)
- Number of rounds impacting (e.g., single main gun HEAT round, three 73mm HEAT rounds, twenty coax rounds)
- Number of weapon systems engaging target (e.g., two M1 tanks may simultaneously engage a T72 or BMP)
- Target vulnerability (e.g., the target's mobility, turret, communications capability)
- Target type (e.g., type of armor, wheeled or tracked)

In addition to determining single weapon effects, a set of force-on-force aggregate models may be required to handle larger scale engagements while minimizing processing requirements. Such a condition may occur in an intensified situation where, for example, three M1 tanks and two BMPs suddenly are exposed to one another simultaneously. Should such a situation occur, it may be beyond the processing capability of

SIMCAT to handle simultaneous firing commands from three M1 tanks and two BMPs, process hit probabilities, and determine damage to targets hit. Another example where aggregate models definitely will be required is with impacting artillery, where the number of targets within a sheath and number of impacting rounds must be considered.

The use of aggregate models for weapon effects requires SIMCAT to compute not only the results of engagements, but also their duration. After determining the expected duration and the loss rates over time at the start of a force-on-force engagement, SIMCAT must allow for the possibility that intervening events will affect the outcome. Specifically, this allows the SIMCAT OPFOR and trainee positions to take some sort of action, such as attempting to disengage, withdrawing, or possibly requesting indirect fire support rather than simply being forced to accept a predetermined outcome for the engagement.

Representation Requirements

The controller/trainer, trainee, and OPFOR engagement representation requirements for SIMCAT are functionally identical, but they will vary dramatically in the manner in which they are satisfied. Therefore, the engagement representation requirements will be discussed first in terms of their functions that will be common to all SIMCAT positions. Following that, the differences in the manner in which engagement representations will be satisfied, depending on the SIMCAT position involved, will be addressed.

The engagement representation requirements for SIMCAT fall into three basic categories--weapon firing, impact of weapon rounds, and effect, if any, of impacting rounds. Specifically, these requirements dictate that SIMCAT represent the following:

- The weapon platform that is firing - The system must indicate whether a BMP, T72, or M1 tank is firing.

- The weapon system aboard the platform that is firing - The system must indicate whether it is the coax or main gun that is being fired on an M1 tank, and whether it is the SAGGER or the 73mm gun that is being fired on a BMP. In the case of the T72, it will always be assumed that the main gun is being fired.

- The impact of weapon system rounds - Auditory and visual cues resulting from rounds impacting down range will be provided to appropriate SIMCAT positions. The positions will include not only the weapon system that fired, but any friendly and OPFOR vehicles that can detect the impacting rounds.

- Weapon signatures - SIMCAT must provide appropriate auditory and visual cues to all SIMCAT vehicles that could detect the signature of a weapon.

- Weapon firing - As appropriate, SIMCAT positions must be made aware of when one of their weapon systems has initiated firing and when it has ceased firing.

- In-Flight representations - Cues resulting from tracers and SAGGER ATGMs in flight must be represented to appropriate SIMCAT positions (providing cues not only to the individual who fires the weapon, but to those individuals who could detect such cues).

- Weapon effects - SIMCAT positions should receive visual and auditory cues that would result from the target being hit (e.g., burning BMP, T72 being blown up, round impacting short/long/left/right). This requirement should not be interpreted to mean that the actual weapon effect(s) would be divulged to a SIMCAT position. For example, should a HEAT round hit but not penetrate a tank turret, the resulting cue would probably be restricted to a flash, a bang, and some smoke in the proximity of the turret that was hit. If the turret is frozen as a result of the hit, only the occupants of the tank that was hit, not the position firing the HEAT round, would be aware of this consequence.

Given that each SIMCAT positions will have a different perception[1] of the battlefield, the manner in which engagement representations will be provided to each position will vary. For example, consider the engagement representation requirements for the M1 tank. SIMCAT must represent the M1 weapon system that is firing (i.e., coax or tank main gun). SIMCAT will represent this differently to each SIMCAT position in the following ways:

- Trainee Position - SIMCAT will probably provide varying auditory cues to represent which of the M1 weapon systems is firing. Visual representations of rounds in-flight (e.g., tracers from the coax), impacting rounds, and weapon effects (e.g., dust, primary and/or secondary explosions, fire, smoke) will be provided to the trainee from the perspective of the tank itself.

- Controller/Trainer Position - The controller/trainer will never need to be provided with auditory cues resulting from the firing of an M1 tank. Nor will the controller/trainer need to be provided with visual representations from the perspective of the M1 tank actually firing. However, the controller/trainer will need representations which will

[1]Perception of the battlefield from the trainee position will be restricted to a view from a single M1 tank; perception from the OPFOR position will be a bird's-eye view of all of his vehicles; and perception from the controller/trainer position will be a view of the entire battlefield and will include all OPFOR and friendly vehicles involved.

enable him to determine which of the four M1 tanks is firing and which weapon system is being fired (i.e., coax or main gun). Unlike the trainee whose tank is firing, the controller/trainer does not need the auditory nor ground level perception representations of these conditions. Instead, these conditions may be represented symbolically.

- OPFOR - The OPFOR position in this example would be provided with appropriate visual and auditory cues depending upon the detection/identification variables discussed previously. When an OPFOR vehicle engages a target (i.e., with a T72 main gun or with either a 73mm gun or SAGGER from a BMP), engagement representations to the OPFOR positions should be quite different from those provided to a trainee position when an M1 weapon system fires. SIMCAT will portray all of the OPFOR vehicles simultaneously. Therefore, when an OPFOR vehicle engages a target, SIMCAT must represent to the OPFOR position which weapon platform is firing (i.e., which BMP or T72) and, if it is a BMP, whether the SAGGER or 73mm gun is firing. These representation requirements may be satisfied through some form of symbology. The approach used to make these representations to the OPFOR position would also satisfy the controller/trainer OPFOR engagement representation requirements.

Indirect Fire

Dedicated indirect fire support will be provided to both friendly (i.e., 155mm) and OPFOR (i.e., 152mm) forces in all SIMCAT scenarios. To satisfy its indirect fire functional requirements, SIMCAT must maintain a record of indirect fire allocations, provide a means for both the friendly and OPFOR forces to request indirect fire support, deliver/impact indirect fires, and represent the effects of indirect fire to all SIMCAT positions. Each of these requirements will be discussed individually.

Fire Support Allocations

No weapon system found on the battlefield has an inexhaustible supply of munitions. As a result, weapon system usage should be tempered and controlled. These are difficult skills to teach and to learn because soldiers tend not to be concerned with such matters in combat. However, this is a reality of combat that SIMCAT must address if it is to avoid negative training.

In a real tactical situation, the only information provided to tactical or maneuver unit leaders regarding indirect fire is whether or not it exists and, if it does exist, whether or not it is dedicated support and the number of batteries supporting them. The point here is that the leaders are never informed of the number of rounds that are available for their support. However, the number of rounds available is

restricted minimally to the basic load of the batteries supporting them. Therefore, SIMCAT must place a ceiling on the number of rounds, by fuze type, that are available to support both the OPFOR and friendly forces. This allocation will never be provided in total to either the OPFOR or friendly forces. However, SIMCAT will monitor the number of rounds fired and the number of rounds remaining. When the supply has been exhausted, SIMCAT will make appropriate notifications (for example, to the controller/trainer as well as to TC, that all of his artillery allocation has been exhausted).

It is difficult to determine the number of rounds by fuze type that should be allocated to OPFOR and friendly forces. Many variables must be considered, including number of batteries in support, size of artillery (e.g., 155mm, 105mm), basic loads, mission of maneuver units being supported, and combat conditions experienced to date by both supporting artillery and maneuver units involved. Most military personnel would agree that it is difficult, if not impossible, to identify any norm(s) considering the number of variables involved and their permutations. However, the idea of an inexhaustible supply of indirect fire support is unrealistic. Therefore, ceilings on the number of rounds available by fuze type must be established for SIMCAT. These are specified in Table 2 below.

The allocations specified in Table 2 are the maximum number of rounds that OPFOR and friendly forces can be allocated during any scenario. The controller/trainer will have the capability to decrease the allocations as he sees fit during initialization of the simulation, but he will not be permitted to allocate more artillery than that specified in the table.

Table 2

Indirect Fire Support Allocations by Fuze Type, Mission, and Force

	NUMBER OF ROUNDS ALLOCATED BY FRIENDLY FORCE'S MISSION		
FUZE TYPE	Movement To Contact	Hasty Attack	Defense
Friendly (155mm):			
DPIC	60	60	40
White Phosphorus	24	24	20
OPFOR (152mm):			
High Explosive, Quick	50	50	200
White Phosphorus	None	None	35

Friendly Force Indirect Fire Requests

Armor platoon leaders normally request indirect fire support in one of two ways: either by direct contact with a Fire Direction Center (FDC) using formal call for fire procedures, or through communications with a FIST FO (Fire Support Team Forward Observer) assigned to his company team. In the latter case, formal call for fire procedures are not required and communications are regimented by sequencing or content protocols. The initial version of SIMCAT will not concern itself with platoon leader/FDC call for fire. All indirect fire support requests will be handled through communications between the platoon leader and/or the platoon sergeant and a FIST FO. To define the functional requirements associated with friendly force indirect fire support, two areas will be addressed. The first area is concerned with the requirements associated with requesting an indirect fire mission. The second is the manner in which the requests are actually processed.

- Indirect Fire Requests - When either the platoon leader or the platoon sergeant decides to request an indirect fire mission, he first will establish contact with the Company Team's FIST FO. This will be done on the Company Team Net. The role of the FIST FO will be assumed by the SIMCAT controller/trainer.

  It will always be assumed that the FIST FO can observe the target that the platoon leader or platoon sergeant is attempting to engage with indirect fire.[1] Therefore, when an indirect fire request is made, the platoon leader or platoon sergeant need only identify the target and specify its location by providing a Spot Report to the FIST FO on the company net, ending with a request for indirect fire. In a real situation, formal call for fire requests communicated to an FDC would then become the responsibility of the FIST FO. In addition, the FIST FO would make any subsequent adjustments necessary to get the indirect fire on target. These adjustments do not (and in SIMCAT, will not) require any communications between the platoon leader or platoon sergeant and the FIST FO.

  Given that the controller/trainer will assume the role of the FIST FO, it will be his responsibility to ensure the indirect fire request received from the platoon leader or platoon sergeant is properly processed.

[1]This, in fact, will be the case because the controller/trainer (acting as the FIST FO) will have a bird's-eye view of the battle. Therefore, the controller/trainer will be capable of accurately interpreting platoon requests made by the platoon leader or the platoon sergeant.

- Request Processing - Having received an indirect fire request from either the platoon leader or platoon sergeant, the controller/ trainer (acting as the FIST FO) will be responsible for actually processing the request. Therefore, the controller/trainer must be able to specify the following to the system:

  - coordinates or adjustments
  - fuze type
  - direction (in mils)
  - number of batteries or rounds to be fired

It is not being suggested that formal call for fire procedures be established between the controller/trainer and SIMCAT. To the contrary, the simplest and most expedient means of conveying this information to SIMCAT is necessary to avoid overburdening the controller/trainer. The use of light pens or touch-sensitive screens would be ideal, but may not be feasible considering SIMCAT cost constraints. Other alternatives which would expedite the input of indirect fire data would include the use of "fill-in-the-blank" forms or menus depicted on the controller/ trainer screen (monitor). Another way to expedite this process would be to include grid lines on the controller/trainer terrain representations. These alternatives should be among those identified and considered.

Given the likelihood that the controller/trainer will be overburdened with processing indirect fire requests (especially adjustments following an initial request), it will be necessary for SIMCAT to automatically make any adjustments following an initial request for fire input to SIMCAT by the controller/trainer. SIMCAT will be able to do this because it will know where the indirect fire targets are, where the initial request impacted, and, therefore, what, if any, subsequent adjustments are necessary. SIMCAT must also consider and reflect any time delays associated with adjustments and the human inaccuracies associated with such adjustments (e.g., seldom, if ever, would the initial adjustment result in the indirect fire impacting directly on the target--especially if it is moving).

OPFOR Indirect Fire Requests

Given that there are no training objectives associated with the OPFOR, the fidelity of the procedures associated with requesting indirect fire support is of no concern. In addition, because there is concern about limiting the procedural burdens placed on the controller/ trainer, the manner in which the OPFOR requests indirect fire support will differ greatly from the way the friendly forces request indirect fire support.

The individual occupying the SIMCAT OPFOR position should not be required to communicate with anyone to request indirect fire support. It is proposed that the same procedure followed by the controller/ trainer to process a friendly force indirect fire request be used by the

OPFOR. That is, he should be able to input the appropriate indirect fire data (e.g., coordinates, direction) directly into SIMCAT using the same simple, expedient means used by the controller/trainer for friendly force fire requests. In addition, as was the case with friendly force indirect fire requests, SIMCAT should automatically make any required adjustments following an initial call for fire request.

Indirect Fire Delivery

Once the SIMCAT system has received an indirect fire request (from either the controller/trainer or OPFOR), it must process the request. Specifically, these functional requirements involve the following:

- Determining the eventual impact area of the requested fire in relation to the locations of all OPFOR and friendly force vehicles.
- Given the aforementioned, determining which of the OPFOR and friendly force vehicles should be provided with auditory and/or visual cues.
- Appropriate timing of the events associated with an indirect fire request (i.e., time from request to shot, time from shot to splash).
- Providing the indirect fire requestor (i.e., controller/trainer or OPFOR) with both "Shot" and "Splash" messages at the appropriate times.
- Maintaining a count of the number of rounds (by fuze type) expended and remaining (for each force) and, when allocations have been expended, informing requestor (i.e., OPFOR and controller/trainer) accordingly.
- Providing the appropriate visual and auditory cues (discussed in detail in the next section).
- Assessing the effects, if any, on targets located in the impact area and providing appropriate cues accordingly.

Representation Requirements

As stated previously, once SIMCAT has determined where indirect fire should impact and has determined who or what can detect the impacting fire, SIMCAT must represent the appropriate cues to certain SIMCAT positions. To determine who can detect the impacting fire, the following factors must be considered:

- Line of sight, which involves terrain relief and vegetation, as well as presence and degree of any obscurants.

- Range from impacting fire to possible detector. Number of batteries fired (i.e., number of rounds impacting).

- Fuze types (including smoke).

- Sheath or pattern in which the indirect fire is impacting (for purposes of SIMCAT, it will be assumed a normal sheath is always used).

These detection criteria will differ to some degree depending upon whether a visual or an auditory cue requirement is being considered by SIMCAT. For example, if a tank (in a defensive position with its engine off) is on one side of a hill, and artillery impacts on the other side, there is no question that a visual cue would not be appropriate. However, it can also be concluded that the occupant(s) of that tank should be provided with some form of auditory cue.

Impacting fire may result in a requirement for SIMCAT to represent either a visual or auditory cue, or possibly both, to SIMCAT positions. The criteria regarding what would be represented should consider the same factors discussed in detail in the section on the SIMCAT detection/identification functional requirements. These criteria differentiate between detection and identification; although a visual or auditory impacting fire cue may be detectable, its identification is dependent upon other variables (primarily range). As a result, there may be a requirement for several impacting fire auditory and visual cues. For example, fire impacting 200 meters away would sound different from fire impacting 2,000 meters away, and both would look different.

Communication

The communication functional requirements for SIMCAT serve three primary purposes. First, they will permit the controller/trainer to interact with other SIMCAT positions in order to control the simulation. Second, they will permit the controller/trainer to monitor tactically related communications for evaluation and feedback purposes. Third, they will provide SIMCAT trainees with a realistic tactical communications environment. Realism in this context means that the communication networks, the participants in those networks (i.e., SIMCAT positions and roles simulated by SIMCAT), and the means of communicating found in field tactical environments will be represented in SIMCAT. Communication functional requirements are divided into five different areas: (1) Communication Network Participants, (2) Communication Networks, (3) Communication Network Selection (4) Hand and Arm Signals, and (5) Jamming.

Communication Network Participants

To understand the communication requirements for SIMCAT, it is first necessary to know what positions or roles will be communicating in

each network as well as who or what will be assuming these roles. There are seven positions or participants involved in the communication networks required by SIMCAT. It should be noted that all seven of these participants will never be involved together in any single SIMCAT communications network (this will be explained in greater detail in the next section). Specifically, the participants involved and whoever or whatever will assume these participatory roles are as follows:

- Trainees - These include the platoon leader, platoon sergeant, TC1, and TC2. The communications requirements of these individuals will be restricted to those normally associated with their positions in a tactical situation.

- Controller/Trainer - The controller/trainer will have the ability to communicate with all trainees (individually and collectively) as well as with the individual occupying the OPFOR position. The purpose of these communications is to control the simulation, provide feedback, and monitor communication activity.

- OPFOR - The individual playing the role of the OPFOR must be provided with a means of communicating with the controller/ trainer. Most of these communications will be related to simulation control.

- Tank Driver - The tank driver of concern here is the driver of the tank controlled by each trainee, but not the driver of any tank controlled by the OPFOR. The driver of a trainee-controlled tank will be a simulated, computer-controlled role capable of recognizing TC driving commands (related to direction and rate of movement) and able to produce minimal voice outputs. Specific requirements of this role are addressed in detail in the section on the movement functional requirements for SIMCAT.

- Gunner/Loader - The gunner/loader of concern here is the gunner/ loader of the tank controlled by each trainee, but not the gunner/ loader of any tank controlled by the OPFOR. The gunner/loader of a trainee-controlled tank will be a simulated, computer-controlled role capable of recognizing firing commands and able to produce minimal voice outputs (i.e., "Identified" and "Up"). Specific voice input/output requirements are addressed in detail in the discussion of the engagement functional requirements for SIMCAT.

- FIST FO - The role of the FIST FO will be assumed by the controller/ trainer in the required communication network. The function of this role will be to receive and process indirect fire requests from the friendly force platoon leader and/or platoon sergeant.

- Company Team Leader - The role of the friendly force company team leader will be assumed by the controller/ trainer. The function of this role will be to provide normal company team leader communications to the friendly force platoon leader and/or platoon sergeant.

Communication Networks

For the purpose of this discussion, communication networks or nets will be discussed in terms of the participants who are to be provided with a capability to communicate with one another on the net and the purpose that the net is intended to serve. SIMCAT requires four communication nets: Platoon, Company Team, Tank Intercom (four each), and Controller. Because four independent and separate tank intercom nets are involved, SIMCAT can be thought of as requiring seven communication nets (especially from a system development view). However, each of the four tank intercom nets are functionally identical. Therefore, these nets will be regarded as one.

The purpose of the four main communication nets are as follows:

- Platoon - Tactical operations net used by all members of tank platoon (i.e., trainees) for C^3 functions.

- Company Team - Tactical operations net enabling communications between all vehicles of the company team. The primary purpose of this net for SIMCAT is to enable the controller/ trainer to role play a company team leader and FIST FO, thus providing the necessary interface in these roles with the platoon leader and/or platoon sergeant.

- Tank Intercom - Involves satisfying communication requirements among each tank driver, gunner/loader, and TC. The primary purpose of this net in SIMCAT is control of movement and fire.

- Controller - Used solely for simulation control purposes, this net permits communications between the controller/ trainer and OPFOR.

Table 3 provides the specifications for each of the required SIMCAT communication nets. The first column specifies the communication net (as described above). The second column identifies the net participants (described earlier). It should be noted that a net participant can be either an individual occupying a SIMCAT position (i.e., trainee, controller/trainer, OPFOR), or a computer-controlled role. All participants will be permitted to transmit, receive/monitor, or both transmit and receive/monitor.

Table 3

SIMCAT Communication Network Requirements

Communication Network	Network Participants
Platoon[a]	Platoon Leader Platoon Sergeant[b] TC1 and TC2 Controller/Trainer
Company Team	Platoon Leader[b] Platoon Sergeant[b] Controller/Trainer FIST FO (role-played by controller/trainer) Company Team Leader (role-played by controller/trainer)
Tank Intercom[c]	TC (i.e., platoon leader, platoon sergeant, TC1 and TC2 Gunner/Loader (computer-controlled voice I/O) Driver (computer-controlled voice I/O)
Controller	OPFOR Controller/Trainer

[a]In SIMCAT, this net will be used to simulate both the radio Platoon Net and the Hot Loop or wire communication network used when the friendly platoon is in defensive positions.

[b]The Platoon Leader and Platoon Sergeant trainee positions must be capable of monitoring the Platoon and Company Team Nets simultaneously. However, they should be able to transmit on only one net at any given time.

[c]Four tank intercom nets (one for each tank) are required. Each of these nets must be independent of the other.

Communication Net Selection

The controller/trainer, platoon leader, and platoon sergeant positions in SIMCAT will have the capability to access several different communication nets (see Table 3). Therefore, each of these individuals must be provided with a means of selecting the communication net in which he wishes to transmit and/ or receive/monitor.

The platoon leader and platoon sergeant must be able to select and then access one of three SIMCAT nets: Platoon Net, Company Team Net, and their individual Tank Intercom Net. Specifically, their communication net selection requirements dictate that they have the capability to:

- Simultaneously monitor both the Company Team and Platoon Nets.
- Select one of three communication networks on which to transmit--Tank Intercom, Platoon, or Company Team. They should not be permitted to transmit on more than one net at any given time.

Each TC must be capable of selecting and then transmitting and receiving on one of two nets: Platoon Net or Tank Intercom Net. Specifically, each TC must be capable of:

- Selecting either the Tank Intercom Net or Platoon Net to monitor.
- Transmitting on either net, but not simultaneously on both.

The controller/trainer net selection requirements dictate that SIMCAT provide the controller/trainer with the capability to:

- Monitor the Platoon Net and Company Team Net.
- Simultaneously monitor the Platoon Net, Company Team Net, and Controller Net.
- Transmit to each trainee position simultaneously over the Platoon Net.
- Select any one of three SIMCAT communication networks on which to transmit: Platoon Net, Company Team Net, or Controller Net.

Hand and Arm Signals

When tank platoons are involved in offensive operations, hand and arm signals are often used for tank platoon communications. Although they may occur less frequently, they are also used by tank platoons in defensive operations. Given their frequency and the ever present need for secure communication networks, it is imperative that SIMCAT permit and facilitate the use of hand and arm signals. Specifically, SIMCAT must provide each of the trainees the ability to:

- Choose from 10 to 20 hand and arm signals he wishes to send.
- Send a selected hand and arm signal.

- Select the recipient (there may be more than one) of a hand and arm signal.

- Receive hand and arm signals.

- Recognize or determine from whom the hand and arm signal is coming.

- Witness or observe hand and arm signals being passed between two tanks other than his own.

The specific hand and arm signals to be incorporated in SIMCAT have yet to be determined; they will vary depending upon the reference source used. However, it is known that there will be a minimum of 10 and a maximum of 20 involved.

Jamming

Electronic Warfare (EW) is a very real threat on the modern battlefield and will be experienced at all Army echelons in combat. Therefore, jamming of SIMCAT communication networks must be considered. As currently envisioned, SIMCAT's jamming functional requirements will involve the following:

- All jamming will be controlled by the controller/trainer. The controller/trainer must be provided with the ability to select the SIMCAT communication network to be jammed (selection alternatives would be restricted to the Platoon and Company Team Nets).

- The controller/trainer must have the ability both to initiate and terminate the jamming of a net.

- Although jamming can manifest itself on a radio net in a variety of ways (e.g., gulls, random noise, wobbler, stepped tones), SIMCAT will be required to simulate only one manifestation.

Resources Audit

More often than not, events on a battlefield are a function of the resources (e.g., weapons, food, fuel) available to the combatants involved. These resources are not inexhaustible and, once expended, can change the course of a battle. The resources of concern to a military leader vary, depending primarily on variables such as time and distances involved. For example, a division commander would have to concern himself about food in a major operation involving several days. A platoon leader, on the other hand, would not concern himself about food given a movement to contact or hasty attack mission involving short distances and short duration. However, both the division commander and platoon

leaders, in the examples given, would be concerned about other resources, such as munitions.

SIMCAT must be sensitive to resources critical to the scenarios it will simulate. This sensitivity is imperative if negative training is to be avoided. For example, if a single M1 Abrams tank is permitted to fire 50 HEAT rounds in a SIMCAT simulation (which far exceeds its basic load of HEAT), negative training would be likely to result. Therefore, SIMCAT must maintain an audit of friendly force and OPFOR resources (i.e., what they started with, what has been expended, what remains, and when a resource has been exhausted).

An inventory of possible military resources would be an ambitious undertaking to develop as well as to reflect in the design of SIMCAT. However, as stated previously, the resources about which one should be concerned vary depending on the nature of the military mission (e.g., duration, distances) under question. In SIMCAT, the focus will be on armor platoon missions or operations involving relatively short periods of time and short traveling distances (e.g., 10 to 40 kilometers). Therefore, only munitions (i.e., basic loads and expenditures of weapon systems involved) and fuel resources (i.e., fuel capacities and fuel consumption rates of vehicles involved) will be of concern. Each of these resources and their resource audit functional requirements will be discussed individually.

Fuel Resource Audit Requirements

SIMCAT should maintain an audit of the amount of fuel used per unit of distance traveled and/or per unit of time while idling; though an M1 consumes approximately an equal amount of fuel whether moving or idling, this may not be true for other vehicles. This requirement can be expressed in terms of a 2 X N table where N equals the number of distinct types of fuel users (e.g., M1, T72, BMP). The first entry for each fuel user type represents the fuel consumption for a given unit of distance traveled. Fuel consumption rates (while vehicle is moving) can be held constant regardless of such things as movement rate, relief, and other factors which have only a marginally different effect on fuel consumption. The second entry for each fuel user type represents the fuel consumption for a given unit of time while idling. Of course, fuel consumption rates while idling will be held constant.

Although fuel resource audit functional requirements are critical to SIMCAT, accurate modeling of fuel consumption rules does not appear to be sufficiently important to warrant extensive development effort. It appears sufficient that fuel consumption be computed at an approximate level. However, the controller/trainer should have the ability to provide for low fuel level conditions for various vehicles if he chooses to initiate a simulation at less than optimal conditions.

In summary, SIMCAT must maintain a fuel resource audit for each vehicle involved in a given simulation. This dictates that SIMCAT:

- Be aware of the fuel level of each vehicle when simulation is initiated.

- Audit the movement of each vehicle and time spent idling in terms of the amount of fuel expended.

- Inform the controller/trainer, appropriate trainee, or OPFOR when a vehicle has exhausted its fuel supply.

- Provide a record at the conclusion of a simulation reflecting the amount of fuel consumed and the amount remaining for each vehicle in the simulation (necessary to provide feedback at the conclusion of a simulation).

Munition Resource Audit Requirements

In the discussion of the engagement functional requirements for SIMCAT, all weapon systems inherent in SIMCAT and their associated basic loads were specified. Given that each weapon system involved in a SIMCAT scenario will have been identified during initialization and that SIMCAT possesses a resident record of the basic load for each weapon system (or a decreased basic load based on controller/trainer modifications made during initialization of a simulation), SIMCAT will be required to:

- Maintain an audit of the munition expenditures of each weapon system (i.e., rounds fired and rounds remaining).

- Inform the controller/trainer and appropriate trainee or OPFOR when a weapon system has exhausted a class of munitions (e.g., when all HEAT rounds in TC1's tank have been exhausted).

- Provide a record at the conclusion of a simulation reflecting the amount and, if appropriate, type of munitions expended and remaining for each weapon system in simulation (this information is critical to adequate trainee feedback).

Time

As a battle simulation, one of the most critical functional requirements of SIMCAT is the representation of time. Two types of time must be represented: real time and simulation time. Each of these will be defined and discussed separately; information regarding the functional requirements related to simulation time will then follow.

Real time refers to the passing of time in the "real world" environment. It is continuous and cannot be controlled. It can be represented by a clock on the wall and, in terms of this discussion, it is external to SIMCAT. Real time relates solely to "real world"

considerations; in the case of SIMCAT, these considerations relate to such things as when to be off the simulator, when to break for lunch, or how long it takes to complete a single SIMCAT scenario.

Simulation time, on the other hand, refers to the passage of time represented in SIMCAT's simulated tactical environment. This passage of time is a critical factor to the combatants (i.e., OPFOR and trainees) involved in the tactical situation. In such an environment, time is an important cue to the existence or nonexistence of an expected event. For example, given a request for indirect fire, the requestor expects certain events at certain times, such as a shot and splash message as well as the artillery actually impacting. Another example would be the expectation of a platoon leader that the tanks in his platoon will simultaneously begin some activity at a specific time. Given that the controller/trainer controls simulation time, OPFOR and trainees can easily lose track of time. For example, if they expect artillery to impact in two minutes and the controller/trainer stops the simulation for five minutes and then begins it again, from their perspective, did the artillery impact three minutes ago or will it impact in two minutes?

Given that SIMCAT must provide all simulation positions (i.e., trainees, OPFOR, and controller/trainer) with some perception of the passage of time within the tactical environment being simulated, certain SIMCAT simulation time functional requirements have been identified.

Simulation Time Requirements

SIMCAT is a battle simulation which will be used to conduct research on how a computer supported battle simulation can be used to train the command, control, and communication skills required during tank platoon operations. As such, SIMCAT must permit the trainer (or in this context, the controller/trainer) to stop a simulation at any point for training purposes (e.g., to point out an error made by a trainee) and/or for administrative purposes (e.g., to break for lunch). In addition, the controller/ trainer must have the ability to replay all or a portion of a SIMCAT simulation. Normally, this will be done at the conclusion of a simulation to show SIMCAT participants what occurred and to permit the controller/trainer to review the just-completed simulation in order to determine what feedback should be provided to the trainees.

To satisfy these training-related processes, there are several time-control functional requirements SIMCAT must satisfy. Specifically, the controller/trainer must be capable of:

- Specifying a specific simulation time he wishes to recall.
- Having accessed a specific simulation time (i.e., a point in a just-completed simulation where the location of all friendly and OPFOR vehicles are shown), accelerating or slowing down (i.e., decelerating) the replay of the simulation events (either forward or backward in time).
- Stopping or freezing in place an in-process simulation or replay of a just-completed simulation.

- Determining the simulation time (as defined previously) in either an in-progress simulation or a replay of a just-completed simulation.

While a simulation is in progress, SIMCAT must allow the controller/ trainer to note simulation times related to critical events or conditions that he may want to recall at the conclusion of the simulation. This capability will provide the controller/trainer an easy and expedient means of noting points in the simulation (which may prove critical to feedback) without disrupting the flow and, therefore, the fidelity of the simulation. Given this capability, the controller/-trainer can review a portion of the just-completed simulation not only in the context of what occurred before the critical incident, but in the context of events/conditions that occurred afterwards. The events/-conditions that occurred following a critical point notation made during the simulation may render invalid the concerns that the controller/-trainer may have had at the time he made the time notation. This critical feature of SIMCAT should discourage the controller/trainer from stopping an in-progress simulation and thereby disrupting its flow and fidelity. Such a situation could occur, for example, if a controller/-trainer were to stop an in-progress simulation to point out that there were no tanks in overwatch only to find out, that in fact, there were, and he had overlooked that detail.

Time Representation Requirements

Simulation time can be presented using an analog device (e.g., clock or watch with hands) or a digital device (e.g., clock or watch with displayed numbers). While either approach can be used to represent time to the SIMCAT participants, the participants must be made aware of the following:

- The starting of time. Participants must be made aware that simulation time has started (or restarted in the event that simulation time has been stopped by the controller/ trainer).

- The passage of time. Participants must be provided the simulation time and be made aware that simulation time is passing. SIMCAT must be capable of presenting simulation time to the participants at normal, accelerated, or decelerated rates.

- The stopping of time. Participants must be made aware that simulation time has been stopped whenever the controller/ trainer decides to stop it.

- The resetting of time. If the controller/trainer decides to reset simulation time to an earlier or later point, the participants must be made aware of this fact and must be shown the point at which the time has been reset.

Post-Simulation

SIMCAT differs from a highly structured procedural or part-task trainer having predetermined conditions, actions and standards. Instead, only the initial conditions (i.e., terrain, TO&Es of two opposing forces, and conflicting missions) are set in SIMCAT. As a result, a multitude of events, actions, and conditions will occur at a very rapid rate during the course of any single SIMCAT simulation. Added to this is the fact that the conditions, events, actions, and outcomes of each scenario simulated in SIMCAT will be unique, making the problem of "what" feedback to provide and "how" to provide it a serious issue. These conditions dictate that SIMCAT must provide the controller/trainer access to data in various forms (e.g., visual, audio, hard copy) from which he can determine what feedback to provide the trainees and how to provide it. The requirements associated with providing feedback have been labeled post-simulation functional requirements.

Post-simulation functional requirements are defined as the SIMCAT processes necessary to support the controller/trainer responsibility to provide feedback to trainees. Post-simulation functional requirements fall into three categories: visual playback, audio or communications playback, and hard copy outputs.

Visual Playback Requirements

One critical aspect of providing feedback related to tactical environments is the ability to reconstruct events, actions, or conditions. In SIMCAT, each of the positions involved will be provided a different perspective of events as they occur. In addition, as the information processing capabilities at each position become overloaded during a simulation, the ability of the trainee to recall events, conditions, or actions accurately will be severely limited. Therefore, SIMCAT must have the capability to record events, conditions, and actions as they occur with total accuracy. This recall requirement of SIMCAT, coupled with the need to reconstruct events, conditions, and actions, has resulted in the identification of the following visual playback functional requirements:

- The controller/trainer must be able to specify a simulation time in hours and minutes (e.g., 1 hour, 31 minutes or 1113 hours) and have SIMCAT recall the situation at that point in time in a just-completed or temporarily halted simulation.

- Given a simulation time, the controller/trainer must be able to specify which perspective he wishes to see (i.e., whatever was seen on the display of the controller/trainer, OPFOR or any one of the trainees).

- The controller/trainer must be able to display perspectives at different SIMCAT positions simultaneously. Suppose, for example, that a controller/trainer wishes to review a

situation in which an M1 tank was destroyed by a SAGGER. To reconstruct this event, it would be advantageous to display simultaneously the perspective of the controller/trainer (i.e., God's-eye view of all vehicles involved), the OPFOR (i.e., what the OPFOR saw at the time), and the trainee whose tank was destroyed. Accomplishing this, the controller/trainer can review the situation from the point of view of each participant and point out what should have happened (e.g., "This is what the OPFOR saw; you should have detected him, and/or had someone in overwatch").

- Given a simulation time, perspective, and station selection, the controller/trainer must have the ability to move forward or backward at either an accelerated or a decelerated rate.

Audio or Communications Playback Requirements

It is understood that SIMCAT will be used for conducting research on training command, control, and communication in a tank platoon. Therefore, it is important that, at the conclusion of a simulation, the controller/trainer be provided the ability to review (prior to providing feedback to trainees) and reconstruct (while providing feedback to trainees) communications which occurred during the just-completed or temporarily halted simulation. This need dictates that SIMCAT record any communication(s) that occurred during the simulation and provide the controller/trainer the ability to access and recall. Given these controller/ trainer feedback requirements, the following audio or communications post-simulation functional requirements have been identified:

- The controller/trainer must be able to select the SIMCAT communication net he wishes to access (i.e., Controller Net, Company Team Net, or Platoon Net, defined and addressed in detail in the discussion of the SIMCAT Communication Functional Requirements).

- Having selected the communication net he wishes to access, the controller/trainer must be able to specify the simulation time (or point in the net's recording) that he wishes to access(e.g., 1 hour, 31 minutes). SIMCAT must then "turn back the clock" to the point designated by the controller/trainer on the communication net specified.

- Given the communication net and simulation time, the controller/trainer must be provided the ability to move forward or backward from that point, and to hear what was communicated. He must be able to move forward or backward at one of three rates: real time, accelerated time, or decelerated time. It should be noted that the controller/ trainer no doubt will synchronize visual playbacks with audio or communication playbacks.

- Given that SIMCAT will have more than one communication output channel (e.g., a "squawk box" at the controller/trainer station, one for each trainee position), the controller/trainer must be able to select the communication output channel on which he wishes the communications to be played. It should also be anticipated that the controller/trainer may desire to play back two synchronized communication nets simultaneously.

Hard Copy Output Requirements

Although the conditions, events, actions, and outcomes of each scenario simulated in SIMCAT will be unique, it can be anticipated that certain data may be critical when providing feedback to the trainees. These data requirements can be viewed as serving two purposes. First, they will provide the controller/trainer with clues about both good and poor performance. As such, the data could prompt the controller/trainer to look for additional information. Suppose, for example, that SIMCAT provided the controller/trainer with a hard copy output outlining when (in simulation time) each friendly vehicle was destroyed or damaged and which OPFOR weapon system caused the destruction or damage. The controller/trainer could use these data to identify the visual and audio or communication points (i.e., simulation time) that he should play back to determine what happened and what feedback, if any, should be provided. The predetermined data could also be used in output form as direct feedback to the trainees, thereby providing each trainee with a listing of the number, type, and time he fired main gun rounds and the OPFOR casualties, if any, that resulted.

Identifying and specifying post-simulation hard copy output requirements for SIMCAT (i.e., content and format) normally requires several analyses (e.g., training objectives, possible events) and a sequential development process. Given the time constraints associated with the development of SIMCAT's functional requirements, however, the procedures normally followed in identifying and specifying the hard copy output requirements cannot be executed. Therefore, the SIMCAT hard copy output functional requirements presented here should be considered preliminary and, as such, subject to change.

As currently envisioned, the post-simulation hard copy outputs for SIMCAT fall into three categories: simulation summary, individual weapon system summary, and indirect fire summary. Each of these is explained below.

- Simulation Summary - This output provides a complete summary of a completed simulation. It is composed of four parts: general information, OPFOR summary, friendly force summary, and a chronological list of losses. The general information part of this output contains the simulation time (i.e., duration of the simulated scenario), playing time (i.e., actual time required to "play" the simulation), identification and date of the scenario played, and names of the individuals responsible for each of the SIMCAT

positions. The next two parts provide a brief summary of each of the opposing forces (i.e., OPFOR and friendly force), specifying the mission of each force, amount of indirect fire allocated, beginning resources, and losses at the conclusion of the simulation. The fourth and last part of this output contains a chronological listing of losses. Losses, in this context, are defined as the destruction or damaging of either an OPFOR or friendly force vehicle. Listed in the sequence they occurred, each loss is specified in terms of the simulation time at which the loss occurred, the nature of the loss (i.e., OPFOR or friendly force vehicle, type of vehicle, and which vehicle, e.g., PSG's Tank), the cause of the loss (indirect fire or, if the result of a direct fire weapon, which vehicle caused the casualty), and the location of the vehicle when it was lost (its grid coordinate). A sample of this output is shown in Figure 1.

- Individual Weapon System Summary - This output would be produced for each of the weapon systems involved in a simulation. Therefore, for an M1 tank, two different Individual Weapon System Summaries would be produced, i.e., one each for the tank main gun and the coax. The heading of this output would identify the weapon system being summarized (e.g., Platoon Leader's Tank Main Gun Summary) and, in parentheses, the name of the individual responsible for that weapon system during the simulation (e.g., 2LT J. K. Ogus). In addition, this output is comprised of two parts: the summary and the engagement record. In the summary part, the type and number of rounds that the weapon system started with would be noted. This would be followed by identification of the rounds expended expressed in terms of both a percentage and number. The mean range at which targets were engaged with the weapon system would then be expressed in meters. A summary of the effects, when using each type of round would then be shown. This summary would list each target (e.g., BMP) that was hit using that type of round and the actual effect (e.g., destroyed or damaged) on the target. Finally, a rounds per hit ratio would then be computed and noted (e.g., 1.5 rounds per hit). The engagement record portion of this output would provide a chronological listing of data related to each time the weapon being summarized was fired. Here the time and type of round fired (if applicable) as well as the location of the weapon system when the round was fired (expressed by a grid coordinate), the type of target being engaged, range of target (expressed in meters), and effect (e.g., missed, destroyed), if any, would be noted. The last entry in the engagement record would always be either the time, location, and what caused the weapon system being summarized to be destroyed, or a notation that the weapon system survived, intact, at the time the simulation was terminated. A sample of this output is shown in Figure 2.

Figure 1. Sample output of simulation summary.

SIMULATION SUMMARY

SIMULATION TIME: 1 hr, 36 min SCENARIO: #1

PLAYING TIME: 2 hrs, 19 min DATE: 9/15/84

PARTICIPANTS:
Controller/trainer - MSG G.L. Smith
OPFOR - 2LT D.L. Jones
PLT LDR - 2LT J.K. Ogus
PSGT - SSG A.D. Killer
TC1 - SGT A.T. Jeep
TC2 - SGT H.E. Quick

OPFOR Summary

MISSION: Hasty Defense

INDIRECT FIRE ALLOCATION: 50 rounds, HE, Quick

RESOURCES: 3 BMPs (each with 4 SAGGER missiles, 40 rounds 73mm HEAT)
1 T72 (40 rounds HAVAPFSDS)

LOSSES: 1 BMP to Indirect Fire
1 T72 to M1 Tank Main Gun

Friendly Force Summary

MISSION: Hasty Defense

INDIRECT FIRE ALLOCATED: 200 rounds, HE, Quick

RESOURCES: 4 M1 Abrams (each with 33 rounds of APFSDS...)

LOSSES: 2 M1 Abrams, both to SAGGERS.

CHRONOLOGICAL LIST OF LOSSES

TIME	OPFOR LOSS	FRIENDLY LOSS	CAUSED BY	LOCATION
0110	T72	---	TC1's Main Gun	Grid 123456
0111	---	TC1's Tank	BMP #1, SAGGER	Grid 126459
0131	---		Mines	Grid 139489
'	'	'	'	'
'	'	'	'	'

Figure 2. Sample output of individual weapon system summary.

PLATOON LEADER'S
TANK MAIN GUN SUMMARY
(2LT J.K. OGUS)

SUMMARY

TYPE ROUND	LOAD	PERCENT	NUMBER	RANGE	EFFECTS	ROUNDS FOR HIT
APFSDS	33	10	3	900 M	1 T72 destroyed 1 BMP damaged	1.5 rounds per hit
HEAT	'	'	'	'	'	'
	'	'	'	'	'	'

ENGAGEMENT RECORD

TIME	ROUND	LOCATION	TARGET	RANGE	EFFECT
0115	APFSDS	Grid 123456	T72	1,100 meters	Missed
0117	APFSDS	Grid 123456	BMP	2,000 meters	Destroyed
'	'	'	'	'	'
'	'	'	'	'	'
0215	PLT LDR'S TANK DESTROYED BY OPFOR SAGGER AT GRID 234567				

- Indirect Fire Utilization Summary - A summary of indirect fire usage would be produced for both the OPFOR and friendly forces. This output would be composed of two parts: the summary and the utilization record. In the summary part, a summary of the indirect fire allocated (by fuze type and number of rounds) and used (in terms of both a number and percentage) would be provided along with their effects (expressed in terms of type and number of vehicles destroyed or damaged), including ratio of rounds used to targets hit. The second part of this output would provide a detailed indirect fire utilization record. Here a chronological listing of all indirect fire requests (whether actually impacted or cancelled) will be presented with related data. For each request, this list will indicate: time of request; time fire impacted; fuze type; number of rounds; location of impact expressed as a grid coordinate; and effects, if any. A sample of this output is shown in Figure 3.

Figure 3. Sample output of indirect fire utilization summary.

FRIENDLY FORCE'S
INDIRECT FIRE UTILIZATION SUMMARY

SUMMARY

FUZE TYPE	ALLOCATION	PERCENT	NUMBER	EFFECTS	ROUNDS PER HIT
High Explosive Quick	60	33	20	1 BMP destroyed T72 Wheel Damaged	10 rounds per hit
White Phosphorus	24	0	0	None	
'	'	'	'	'	
'	'	'	'	'	

UTILIZATION RECORD

REQUESTED	IMPACTED	FUZE TYPE	# OF ROUNDS	LOCATION OF IMPACT	EFFECT(S)
0113	0115	HE,Quick	6	Grid 123456	T72 Wheel Damaged
0120	0122	HE,Quick	12	Grid 124457	None
0215	N/A	HE,Quick	6	Request Cancelled	N/A
'	'	'	'	'	'
'	'	'	'	'	'

TASK II: DETERMINATION OF COMPUTER AND DEVICE CHARACTERISTICS AND SYSTEM SPECIFICATIONS

The purpose of the activities conducted during Task 2 was to design a computer supported battle simulation able to meet as many of the SIMCAT functional requirements as possible. According to the requirements of the contract, two different versions of SIMCAT were to be designed--a low cost version ($50,000) and a high cost ($150,000) version.

The first step in the preparation of the system specifications was to collect detailed information on computers with 8 and 16 bit processors considered possible candidates for SIMCAT. As part of this effort, a review was conducted of periodicals devoted to computers and those that provided hardware specification overviews. In addition, conversations were held with computer specialists, and reports from previous projects were reviewed. When necessary, manufacturers of computer equipment were contacted and asked to provide literature describing their systems.

The results of these reviews were compiled and provided to ARI. Included were descriptions of 51 different computers or computer systems. Contained in these descriptions was information on memory, available operating systems, communications protocols, graphics, networking, and costs.

As this information was being collected, sufficient progress was being made in the identification of the functional requirements for SIMCAT that it became possible to identify certain computer characteristics that would be required to meet these requirements. It became apparent, for example, that a multi-user system having only one processor would not be able to handle the graphics and voice requirements of SIMCAT. Instead, a system with distributed processing (i.e., a separate computer at each station) would be required in which several processors would be linked in a local area network. This narrowed the search to microcomputers with 16 bit processors that could be linked in this manner.

With the completion of the initial draft of the functional requirements for SIMCAT, additional hardware requirements for SIMCAT could be identified. It was apparent that the computer selected for SIMCAT would have to interface with peripherals providing voice recognition, sound/-speech synthesis, graphics processing, videodisc control, and local area network interfacing. Moreover, the peripherals would have to be available as "off the shelf" products since the developmental costs could not be supported by available funding. In addition, ARI made it known that the low cost version of SIMCAT would be selected for development and stressed repeatedly that the system must be extremely reliable even if this requirement could only be achieved by sacrificing technological sophistication. As a consequence, the IBM Personal Computer was selected as the microcomputer that was most able to be expanded to meet all of the requirements of SIMCAT with the least risk.

Once the IBM Personal Computer was selected for SIMCAT, a detailed comparison was made of the hardware, software, and peripherals that were available for this computer. Performance comparisons were then made in terms of the final set of functional requirements taking into account the funds that were available for the purchase of the system components. It became apparent at this time that certain critical requirements could not be met at the lower cost option. To maintain this cost figure would require giving up voice recognition and speech/sound synthesis. Moreover, it would require that each SIMCAT participant (i.e., all four trainees, controller/trainer, OPFOR) have the same view of the battlefield. However, since these deficiencies could be overcome for an additional amount of funding, the spending limit for the low cost system was increased to $60,000. In addition, a videodisc map display was produced that would be used for all SIMCAT stations. The final list of components for the low cost configuration of SIMCAT are contained in Table 4.

Table 4

SIMCAT Hardware and Software Configuration

Components[a]	Quantity
COMMON TO ALL POSITIONS	
IBM PC Personal Computer with 64K RAM	6
512K 200ns RAM (with parity check)	6
Tecmar Graphics Master Board	6
Sony LDP 1000A Video Disc Player	6
Sony 12" High Res Color Monitor PVM 1270Q	6
IBM PC XT Power Supply	6
JetDrive RAM Disk Driver	6
Xnet Expansion Card	6
CONTROLLER STATION	
Streaming Tape Backup System	1
IBM Monochrome Monitor	1
IBM Monochrome Adaptor and Parallel Printer Card	1
360KB Sanyo Floppy Disk Drive Unit	1
LNW BusBoard w/Floppy Disk Controller, serial port, clock module	1
Logitech Mouse (Input Device)	1
C. Itoh Dot Matrix Printer	1

(table continues)

Table 4 (cont'd)

TANK COMMANDER STATIONS	
Hayes Products Mach III Joystick	4
Function Keyboard	4
1.2MB Mitsubishi Floppy Disk Drive	4
360KB Sanyo Floppy Disk Drive	4
LNW BusBoard w/Floppy Disk Controller, serial port, game port	4
Votan Speech Recognition/Reproduction Board	4
OPFOR STATION	
1.2 MB Mitsubishi Floppy Disk Drive	1
360KB Sanyo Floppy Disk Drive	1
LNW BusBoard w/Floppy Disk Controller, serial port	1
Logitech Mouse	1
GENERAL SYSTEM REQUIREMENTS	
Miscellaneous Fabrication Cables, and Equipment	NA
8087 Numeric Coprocessor Chip	1
Standard 5 1/4" DS/DD floppy disks	20
Super High Density 5 1/3" DS floppy disks	40
Driver for Mitsubishi Floppy	1
IBM PC 64K RAM, one DS/DD Floppy Drive	1
192K 200ns RAM (with parity check)	1
External Syn Source and Distributed Amplifier System	1
Xcomp 31.5MB Hard Disk	1
Xcomp Expansion Card	1
JetDrive RAM Disk Driver	1
IBM DOS 2.1 Operating System	7
Logi Tech Modula2-86	1
IBM Technical Reference Manual	1
IBM DOS 2.1 Technical Reference Manual	1
V-Edit Text Editor	1

[a]While specific products are listed, they may be replaced by equivalent products due to the bid process.

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